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FINAL ENHANCED NATURAL ATTENUATION TREATABILITY STUDY WORK PLAN SITE 1140NW WITH TRANSMITTAL NAS PENSACOLA FL
7/10/2002
TETRA TECH

0001

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Document Tracking No. 02JAX0181

July 10, 2002

Project Number N4250

Florida Department of Environmental Protection
ATTN: Tracie Vaught
Remedial Project Manager
2600 Blairstone Road Mail Station 4535
Tallahassee, Florida

Reference: Clean Contract Number N62467-94-D-0888
Contract Task Order Number 0249

Subject: Final Enhanced Natural Attenuation Treatability Study Work Plan
for Site 1140NW
Outlying Landing Field Bronson
Pensacola, Florida

Dear Ms. Vaught:

Tetra Tech NUS Inc. (TtNUS) is pleased to submit the Final Enhanced Natural Attenuation Treatability Study Work Plan for Site 1140NW at Outlying Landing Field Bronson, Pensacola, Florida for your review and approval. An additional copy has been forwarded to Naval Air Station Pensacola as indicated below.

If you have any questions regarding the enclosed material, or if I can be of assistance in any way, please contact me at (850) 385-9899, or e-mail at walkerg@ttnus.com.

Sincerely,

(for) Gerald Walker, P.G.
Project Manager

Enclosures

cc: Mr. B. Glover, SOUTHDIV
Mr. G. Campbell, NAS Pensacola
Ms. D. Wroblewski, TtNUS (cover letter only)
Mr. M. Perry, TtNUS (unbound copy)
Project Office File

Enhanced Natural Attenuation Treatability Study Work Plan

for

Site 1140NW

Outlying Landing Field Bronson

Pensacola, Florida

Southern Division
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888
Contract Task Order 0249

July 2002

02JAX0153

TREATABILITY STUDY WORK PLAN
FOR
SITE 1140NW

OUTLYING LANDING FIELD BRONSON
PENSACOLA, FLORIDA

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
Southern Division
Naval Facilities Engineering Command
2155 Eagle Drive
North Charleston, South Carolina 29406

Submitted by:
Tetra Tech NUS, Inc.
661 Andersen Drive
Foster Plaza 7
Pittsburgh, Pennsylvania 15220

CONTRACT NUMBER N62467-94-D-0888
CONTRACT TASK ORDER 0249

JULY 2002

PREPARED UNDER THE SUPERVISION OF:

(for) GERALD WALKER
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TETRA TECH NUS, INC.
TALLAHASSEE, FLORIDA

APPROVED FOR SUBMITTAL BY:

Debra M Wroblewski
DEBBIE WROBLEWSKI
PROGRAM MANAGER
TETRA TECH NUS, INC.
PITTSBURGH, PENNSYLVANIA

The professional opinions rendered in this decision document identified as Enhanced Natural Attenuation Treatability Study Work Plan for Site 1140NW, Outlying Landing Field Bronson, Pensacola, Florida were developed in accordance with commonly accepted procedures consistent with applicable standards of practice. This document was prepared under the supervision of the signing engineer and is based on information obtained from others. If conditions are determined to exist differently than those described in this document, then the undersigned professional engineer should be notified to evaluate the effects of any additional information on the project described in this document.

Gregory S. Roof, P.E.
Professional Engineering Number 50842
Tetra Tech NUS, Inc. Engineering No. 7988

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APPENDICES

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ACRONYMS

bls	Below Land Surface
CARA	Contamination Assessment Report Addendum
cc/min	Cubic Centimeters per Minute
CIH	Certified Industrial Hygienist
CLEAN	Comprehensive Long-term Environmental Action Navy
CompQAP	Comprehensive Quality Assurance Plan
CTO	Contract Task Order
cwm	clear wide mouth
°C	Degrees Celsius
DO	Dissolved Oxygen
EDB	Ethylene Dibromide
EISOPQAM	Environmental Investigation Standard Operating Procedures and Quality Assurance Manual
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FL-PRO	Florida Petroleum Range Organics
ft	Feet/Foot
ft^3	Cubic Feet
ft^3/min	Cubic Feet per minute
FOL	Field Operations Leader
GCTLs	Groundwater Cleanup Target Levels
H^2SO^4	Sulfuric Acid
HASP	Health and Safety Plan
HCl	Hydrogen Chloride
HDPE	High Density Polyethylene
HSM	Health and Safety Manager
IDW	Investigation-derived Waste
ISOC™	in situ Submerged Oxygen Curtain
iTi	inVenture Technologies, Inc.
MOP	Monitoring Only Plan
NA	Natural Attenuation
NAS	Naval Air Station
Navy	United States Navy
NPWC	Navy Public Works Center
O&M	Operations and Maintenance

ACRONYMS (Continued)

OLF	Outlying Landing Field
ORP	Oxidation Reduction Potential
PAHs	Polycyclic Aromatic Hydrocarbons
PPE	Personal Protective Equipment
psi	Pounds per Square Inch
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
ROI	Radius of Influence
RPM	Remedial Project Manager
SC	Specific Conductivity
SCTLs	Soil Cleanup Target Levels
SOPs	Standard Operating Procedures
SOUTHNAVFACENGCOM	Southern Division, Naval Facilities Engineering Command
TOC	Total Organic Carbon
TRPH	Total Recoverable Petroleum Hydrocarbons
TSWP	Treatability Study Work Plan
TtNUS	Tetra Tech NUS, Inc.
μg/L	Micrograms per Liter
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tanks
VOCs	Volatile Organic Compounds

1.0 INTRODUCTION

This Enhanced Natural Attenuation (NA) Treatability Study Work Plan has been prepared by Tetra Tech NUS, Inc. (TtNUS) under the Comprehensive Long-term Environmental Action Navy (CLEAN) Contract Number N62467-94-D-0888 Contract Task Order (CTO) 0249 for the United States Navy (Navy) Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM). This work plan has been prepared to develop application and testing methodology to determine if enhanced NA is an appropriate remedial technology for the Site 1140NW Outlying Landing Field (OLF) Bronson located at Pensacola, Florida. The scope of this Treatability Study is limited to the documented groundwater contamination that has been previously identified at the site.

The purpose of this Treatability Study is to determine if *in situ Submerged Oxygen Curtain* (ISOC™) technology can significantly reduce petroleum-impacted groundwater at Site 1140NW. This TSWP incorporates data presented in the Contamination Assessment Report Addendum (CARA) for Site 1140NW [Navy Public Works Center (NPWC), 1998], Letter Report: Re-sampling of Monitoring Wells MW-3 and MW-6, Site 1140NW OLF Bronson (TtNUS, 2000a), Initial Semi-annual Monitoring for Natural Attenuation Letter Report: Site 1140NW OLF Bronson, Pensacola, Florida (TtNUS, 2000b), and the Letter Report: Supplemental Site Assessment Sampling Site 1140NW, OLF Bronson, Pensacola, Florida (TtNUS, 2001).

1.1 DOCUMENT ORGANIZATION

Section 1.0 of this report presents this introduction, a detailed site description, the project scope, and project goals. Section 2.0 describes the proposed field investigation activities. Section 3.0 describes the environmental sampling and analysis activities. Section 4.0 describes management aspects of the project such as management structure, reporting requirements, and quality assurance (QA) activities. The ISOC™ User Guide and information about ISOC™ technology with Florida Department of Environmental Protection (FDEP) approval are included in Appendices A and B, respectively.

1.2 SITE DESCRIPTION

1.2.1 Site Assessment History

From 1996 to 2000 contamination assessment activities were performed at Site 1140NW, OLF Bronson (Figure 1-1), Pensacola, Florida to determine the extent of petroleum impacted soil and groundwater at the site. A Contamination Assessment and Contamination Assessment Addendum were conducted at Site 1140NW in 1997 and 1998, respectively. The assessment activities at Site 1140NW resulted in a Monitored NA Plan approved by the FDEP on May 8, 2000. Subsequent to the approved Monitored NA Plan, TtNUS performed the initial monitored NA groundwater sampling in May 2000. Results of the initial

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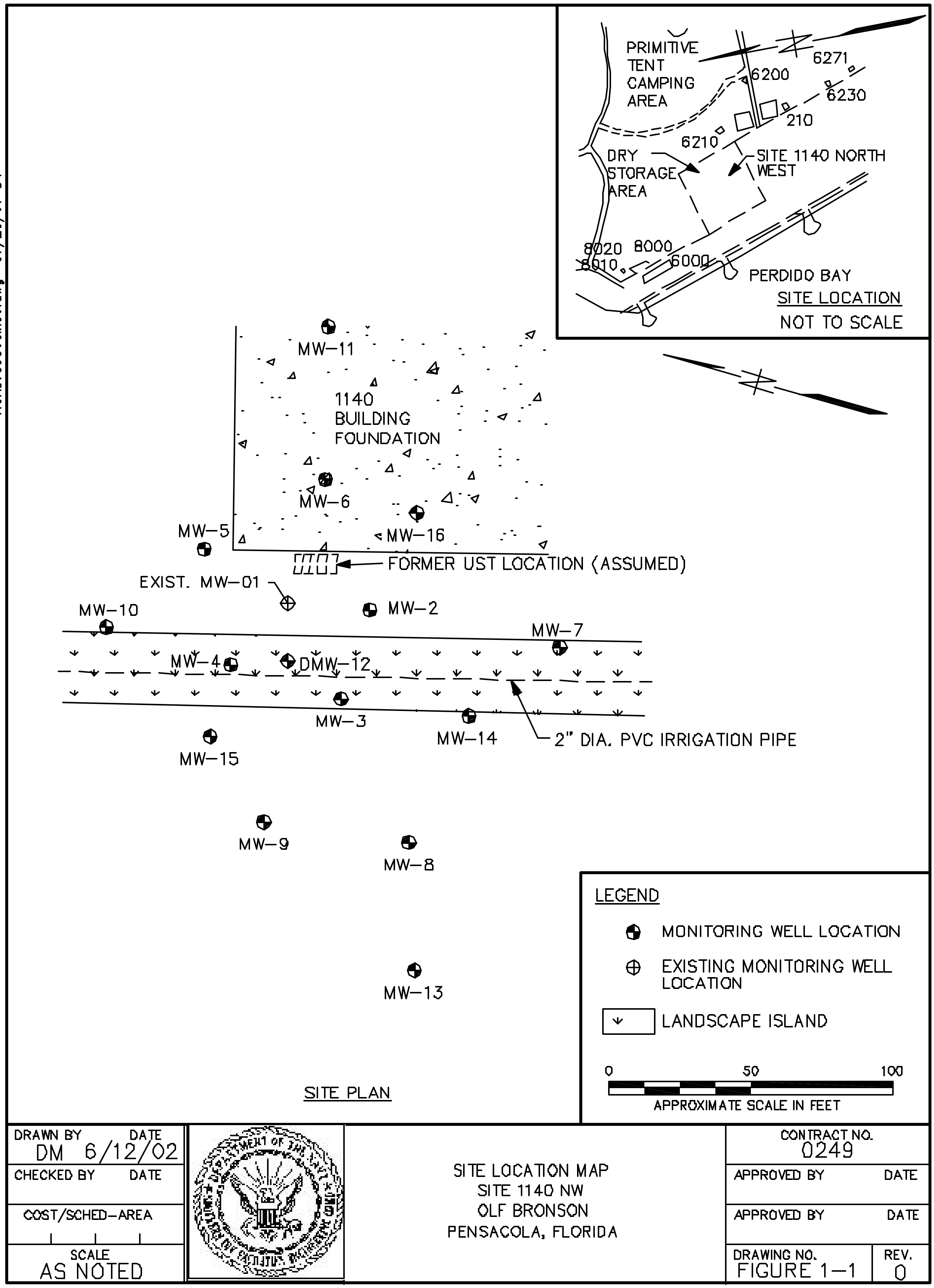

FORM CADD NO. SDIV_AV.DWG - REV 0 - 1/20/98 monitored NA sampling event indicated dissolved petroleum contaminants in groundwater exceeded FDEP site-specific action levels. As a result of the exceedance of action levels, TtNUS conducted Supplemental Site Assessment Sampling in May 2001. Supplemental site assessment activities resulted in the recommendation that a treatability study be completed at the site. This work plan is for a Treatability Study at Site 1140NW with ISOC™ technology. ISOC™ is an innovative technology, which diffuses oxygen into the groundwater and increases the microbial population, thereby enhancing biodegradation of the dissolved petroleum contaminant plume.

1.2.2 Site Investigation Summary

The following reports have previously been prepared to investigate and monitor petroleum compounds detected in site groundwater and were used in the development of this work plan:

Contamination Assessment Report Addendum (NPWC, 1998). A Contamination Assessment Report was prepared by NWPC in 1997 to assess the extent of petroleum compounds in soil and groundwater at Site 1140NW. The contaminant source was reported to be a former underground storage tank (UST), which was located adjacent to and west of former Building 1140 (Figure 1-1). The CARA addressed the comments of the FDEP for the Site 1140NW Contamination Assessment Report.

During CARA assessment activities the NPWC collected groundwater samples from monitoring wells MW-1, MW-2, MW-4, and MW-9 in July 1998 (see Figure 1-1). The groundwater samples were analyzed for polynuclear aromatic hydrocarbons (PAHs), ethylene dibromide (EDB), and total recoverable petroleum hydrocarbons (TRPH). As reported in the CARA, a groundwater sample was not collected from MW-3 because it was destroyed during a beautification project. New monitoring wells (MW-14, MW-15, and MW-16) were installed at Site 1140NW and groundwater samples were analyzed for EDB, PAHs, and TRPH from MW-14, and for EDB from wells MW-15 and MW-16. Results of the CARA field activities indicated PAHs and TRPH detected in monitoring wells MW-1 and MW-9, but at concentrations below FDEP Groundwater Cleanup Target Levels (GCTLs). The CARA recommended a Monitoring Only Plan for NA for Site 1140NW with the sampling of a replacement well MW-3, plus the sampling of existing wells MW-1, MW-6, MW-9, and MW-11.

Letter Report: Re-sampling of Monitoring Wells MW-3 and MW-6, Site 1140 NW, OLF Bronson, Pensacola, FL (TtNUS, 2000a). This report presented the results of additional groundwater sampling completed by TtNUS in response to the FDEP's comments on the CARA. In November 1998, the FDEP issued comments to the CARA that proposed monitoring wells MW-6 and MW-3 (a replacement well at that location) be re-sampled. The data would be used for additional evaluation before preparation of an FDEP NA Monitoring Plan Approval Order. In October 1999, TtNUS installed a replacement monitoring well MW-3, and collected groundwater samples from wells MW-3 and MW-6. The locations of these monitoring wells are shown in Figure 1-1. The groundwater samples were analyzed for PAHs, EDB, and TRPH. Results of the groundwater sample analysis from monitoring well MW-3 indicated concentrations of PAH compounds 1-methlynaphthalene (190 micrograms per liter (µg/L)), 2-methlynaphthalene (130 µg/L), and naphthalene (66 µg/L) were above the Chapter 62-777 FDEP GCTLs of 20 µg/L for each constituent. Anthracene, flourene, and 1-methylnaphthalene were detected in monitoring well MW-6 at concentrations below the FDEP GCTLs. Based on the analytical results from monitoring wells MW-3 and MW-6, the letter report proposed a NA Monitoring Approval Order with the groundwater monitoring conducted as outlined in the CARA.

Initial Semi-annual Monitoring Report for Site 1140NW OLF Bronson, Pensacola, FL (TtNUS, 2000b). This letter report presented the results of the initial semi-annual monitoring event of groundwater for NA in response to the FDEP's letter dated May 8, 2000. The May 8, 2000 FDEP letter approved the NA Monitoring Plan for Site 1140NW and proposed that monitoring wells MW-3, MW-8, and MW-9 be sampled for PAHs semi-annually for a period of two years. On May 25, 2000, TtNUS personnel collected groundwater samples from monitoring wells MW-3, MW-8 and MW-9 in accordance with the NA Monitoring Plan for Site 1140NW. The location of monitoring wells MW-3, MW-8, and MW-9 are indicated on Figure 1-1.

Results of the initial monitoring event indicated that groundwater flow continued to be westerly. Groundwater analytical results indicated five analytes were detected in the groundwater samples at concentrations exceeding instrument detection limits. Three analytes (naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene) were detected at concentrations exceeding FDEP's designated site-specific action levels. 1–Methylnaphthalene and 2-methylnaphthalene were detected in the groundwater sample from source area monitoring well MW-3 at concentrations of 240 µg/L and 110 µg/L, respectively. The FDEP's designated action level for each of these analytes in the source area is 200 µg/L. Naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene were detected in site perimeter monitoring well MW-8 at concentrations of 37 µg/L, 33 µg/L, and 25 µg/L, respectively. The FDEP's designated site-specific action level for each of these analytes in site perimeter monitoring wells is 20 µg/L. Monitoring wells MW-3 and MW-8 were re-sampled on June 23, 2000 for confirmation. Analytical results confirmed 1-methylnaphthalene (300 µg/L) exceeded action levels in MW-3. Action levels were exceeded in MW-8 for naphthalene (24 µg/L) and 1-methylnaphthalene (29 µg/L). Based on the findings, it was recommended in the letter report that a supplemental site assessment be completed to: (1) Determine if an additional continuing source area was present in the groundwater smear zone; (2) If groundwater contaminant concentrations across the site had changed; and (3) If upgradient sources were present.

Letter Report: Supplemental Site Assessment Sampling, Site 1140NW OLF Bronson, Pensacola, Florida (TtNUS, 2001). Based on the results of the initial semi-annual monitoring, the FDEP canceled the

NA Approval Order in a letter dated August 31, 2001, and concurred with the proposal for a supplemental site assessment. In response, TtNUS conducted supplemental site assessment sampling and presented the results in the above titled letter report.

The Supplemental Site Assessment was conducted in May and June 2001. The assessment included six soil borings that were installed down to the water table in the area of the former UST location and the collection of soil samples in the area of groundwater table fluctuation (i.e. smear zone) for PAH analysis. Soil borings SB-1 through SB-6 were advanced to the water table at the locations shown on Figure 1-2. Twelve PAHs were detected in the soil, however all detected concentrations were below the direct exposure and leachability limits for Soil Cleanup Target Levels (SCTLs) from Chapter 62-777, Florida Administrative Code (FAC). In June 2001, TtNUS personnel measured depth to groundwater, and collected groundwater samples from the monitoring wells. Monitoring wells MW-1, MW-2, MW-3, MW-4, MW-5, MW-6, MW-8, MW-9, MW-11, DMW-12, and MW-13 were sampled and analyzed for PAHs. The groundwater flow direction was determined to be primarily in a westerly direction (see Figure 1-3). Seventeen PAHs were detected in the groundwater samples from Site 1140NW. A summary of analytes detected is provided as Table 1-1. Three of the analytes, naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene, were detected at concentrations exceeding FDEP's GCTLs. Naphthalene and 1-methylnaphthalene were detected in site perimeter monitoring well MW-8 at concentrations of 22 and 45 µg/L, respectively. 1-Methylnaphthalene and 2-methylnaphthalene were detected in monitoring well MW-3 at concentrations of 100 µg/ and 31 µg/L, respectively. The FDEP GCTLs for each of these analytes is 20 µg/L. None of the groundwater samples from the additional wells contained any PAHs in exceedance of GCTLs. The Supplemental Site Assessment concluded that no determination could be made as to the source of the elevated PAH analytes detected in monitoring wells MW-3 and MW-8. The report recommended a Treatability Study be completed at the site.

1.3 NATURE AND EXTENT OF GROUNDWATER CONTAMINATION

Groundwater contamination has been documented at the site during all four of the above-referenced assessment activities. Table 1-1 provides a summary of the most recent groundwater analytical results for site monitoring wells at Site 1140NW. The groundwater contamination appears to be limited from source well MW-3 to downgradient monitoring well MW-8. Therefore, this Treatability Study is aimed at addressing the groundwater contamination located in the vicinity of monitoring wells MW-3 and MW-8.

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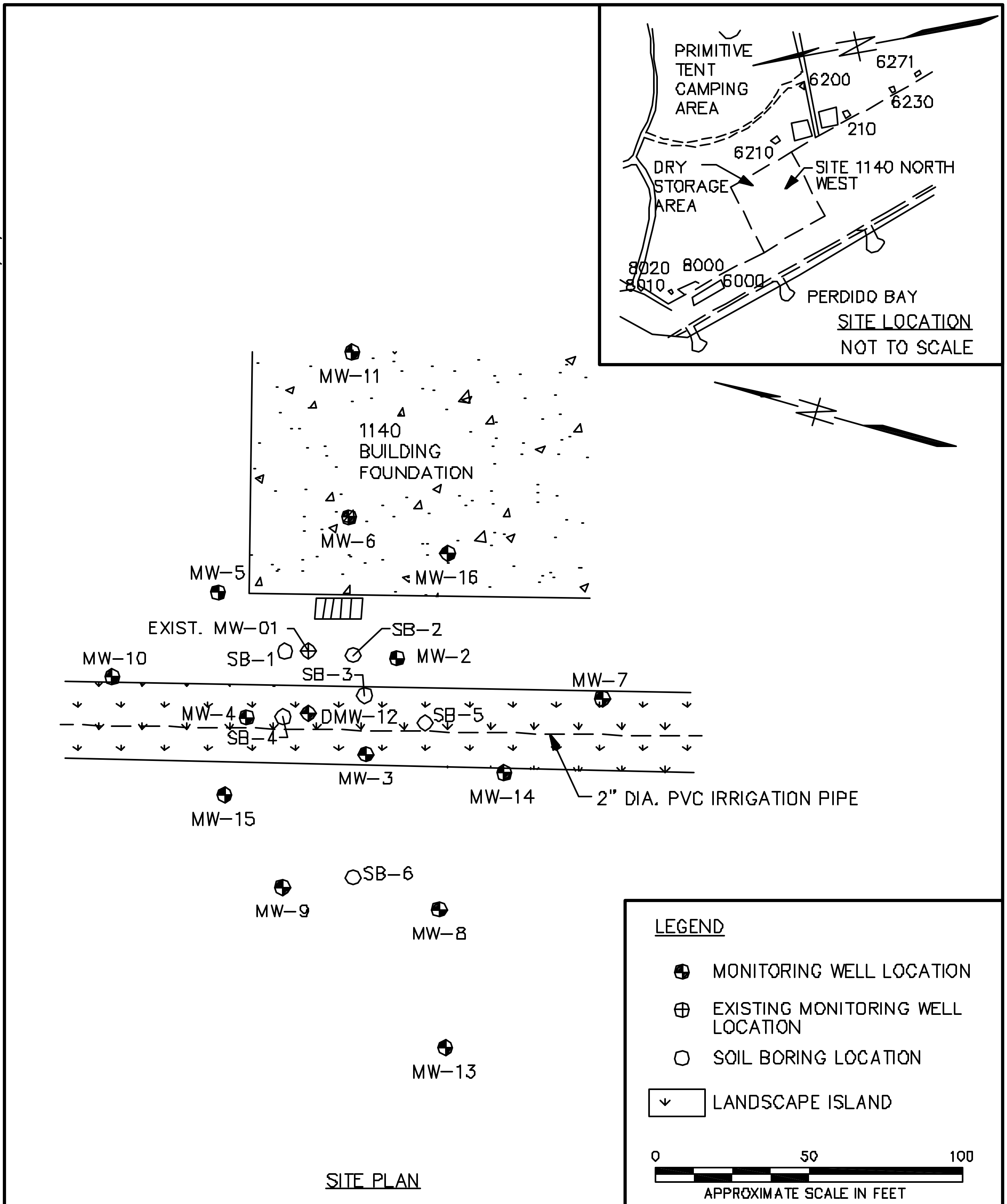

SITE PLAN

DRAWN BY DM DATE 6/12/02	MONITORING WELL AND SOIL BORING LOCATIONS SITE 1140 NW OLF BRONSON PENSACOLA, FLORIDA	CONTRACT NO. 0249
CHECKED BY DATE		APPROVED BY DATE
COST/SCHED-AREA		APPROVED BY DATE
SCALE AS NOTED		DRAWING NO. FIGURE 1-2 REV. 0

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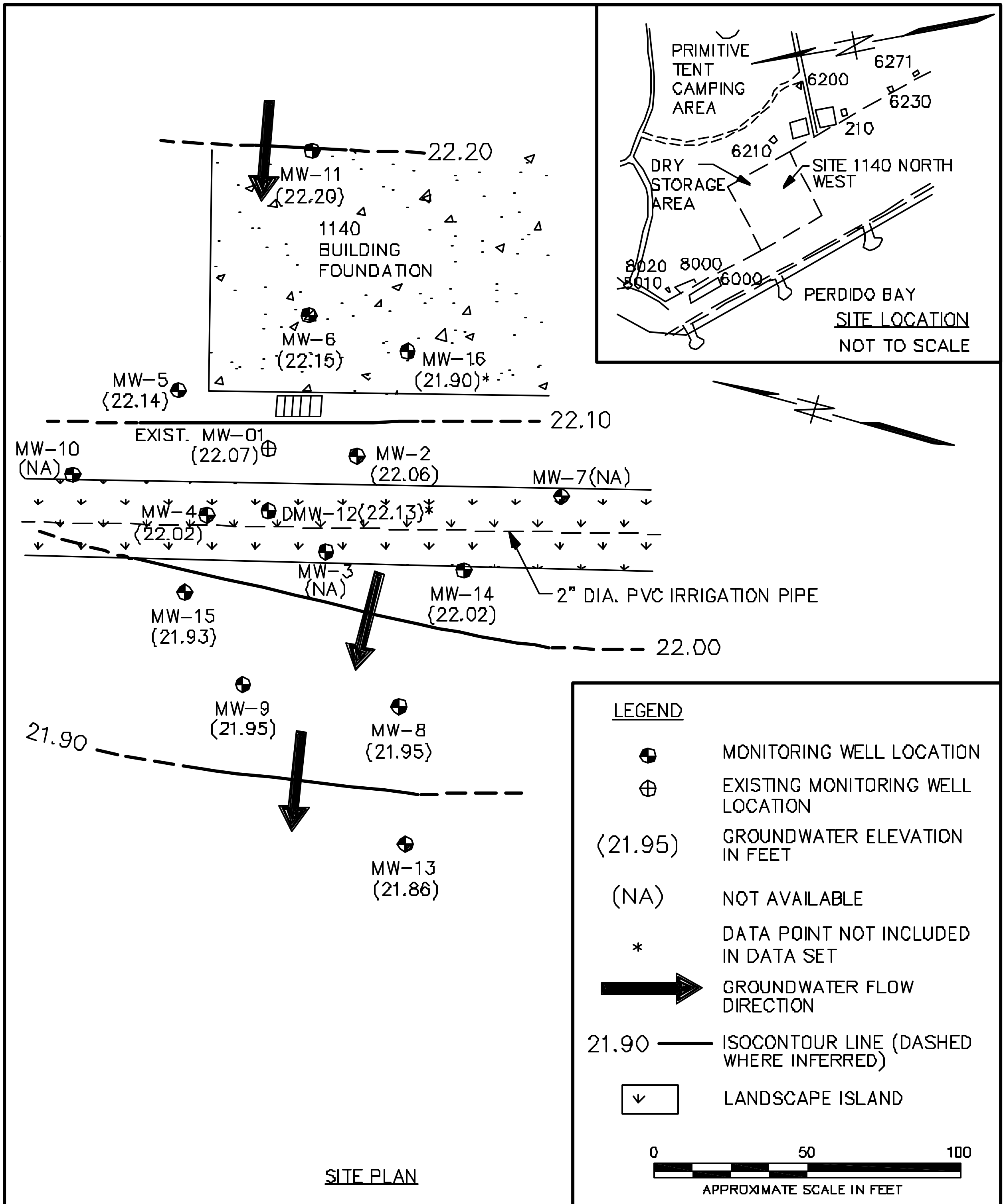

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DRAWN BY DM	DATE 6/12/02		POTENTIOMETRIC SURFACE MAP FOR JUNE 5, 2001 SITE 1140 NW OLF BRONSON PENSACOLA, FLORIDA	CONTRACT NO. 0249	
CHECKED BY	DATE			APPROVED BY	DATE
COST/SCHED-AREA				APPROVED BY	DATE
SCALE AS NOTED				DRAWING NO. FIGURE 1-3	REV. 0

FORM CADD NO. SDIV_AV.DWG - REV 0 - 1/20/98

TABLE 1-1
SUMMARY OF ANALYTES DETECTED IN PERIMETER WELLS
SITE 1140NW
OUTLYING LANDING FIELD BRONSON
PENSACOLA, FLORIDA

Sample Location Collect Date		Monitoring Well No. 8 6/5/2001	Monitoring Well No. 9 6/5/2001	FDEP Site-specific action levels/milestones for Site 1140NW perimeter wells [2]
	GCTLs [1] (µg/L)			
PAHs (USEPA Method SW-846 8310 µg/L)				
1-Methylnaphthalene	20	**45**	ND	20 / <20
2-Methylnaphthalene	20	ND	5.0	20 / <20
Acenaphthylene	210	ND	6.6	none
Anthracene	2,100	0.6	ND	none
Benzo(a)anthracene	0.2	ND	ND	none
Benzo(b)fluoranthene	0.2	ND	ND	none
Benzo(k)fluoranthene	0.5	ND	ND	none
Benzo(g,h,i)perylene	210	ND	ND	none
Benzo(a)pyrene	0.2	ND	ND	none
Chrysene	4.8	ND	ND	none
Dibenzo(a,h)anthracene	0.2	ND	ND	none
Fluoranthene	280	1.8	ND	none
Fluorene	280	8.0	3.4	none
Indeno(1,2,3-cd)pyrene	0.2	ND	ND	none
Phenanthrene	210	ND	1.0	none
Naphthalene	20	**22**	5.0	20 / <20
Pyrene	210	ND	ND	none

[1] GCTLs as provided in Chapter 62-777, F.A.C.

[2] As provided in FDEP letter dated May 8, 2000.

USEPA = United States Environmental Protection Agency

Bold indicates an exceedance of action levels and/or GCTLs.

ND = Analyte was not detected.

TABLE 1-1 (CONTINUED)
SUMMARY OF ANALYTES DETECTED IN PERIMETER WELLS
SITE 1140NW
OUTLYING LANDING FIELD BRONSON
PENSACOLA, FLORIDA

Sample Location Collect Date		Monitoring Well No. 3 6/5/2001	Duplicate of Monitoring Well No. 3 6/5/2001	FDEP Site-specific action levels/milestones for Site 1140NW contaminated wells [2]
	GCTLs [1] (µg/L)			
PAHs (USEPA Method SW-846 8310 µg/L)				
1-Methylnaphthalene	20	**100**	**110**	200/110
2-Methylnaphthalene	20	**31**	**33**	200/110
Acenaphthylene	210	ND	ND	none
Anthracene	2,100	ND	ND	none
Benzo(a)anthracene	0.2	ND	ND	none
Benzo(b)fluoranthene	0.2	ND	ND	none
Benzo(k)fluoranthene	0.5	ND	ND	none
Benzo(g,h,i)perylene	210	ND	ND	none
Benzo(a)pyrene	0.2	ND	ND	none
Chrysene	4.8	ND	ND	none
Dibenzo(a,h)anthracene	0.2	ND	ND	none
Fluoranthene	280	ND	ND	none
Fluorene	280	9.0	9.0	none
Indeno(1,2,3-cd)pyrene	0.2	ND	ND	none
Phenanthrene	210	ND	ND	none
Naphthalene	20	ND	10	200/110
Pyrene	210	ND	ND	none

[1] GCTLs as provided in Chapter 62-777, F.A.C.
[2] As provided in FDEP letter dated May 8, 2000.
USEPA = United States Environmental Protection Agency
Bold indicates an exceedance of action levels and/or GCTLs.
ND = Analyte was not detected.

TABLE 1-1 (CONTINUED)
SUMMARY OF ANALYTES DETECTED IN ADDITIONAL WELLS
SITE 1140NW
OUTLYING LANDING FIELD BRONSON
PENSACOLA, FLORIDA

Sample Location		Monitoring Well No. 1	Monitoring Well No. 2	Monitoring Well No. 4	Monitoring Well No. 5
Collect Date		6/6/2001	6/6/2001	6/6/2001	6/6/2001
	GCTLs [1] (µg/L)				
PAHs (USEPA Method SW-846 8310 µg/L)					
1-Methylnaphthalene	20	ND	ND	ND	ND
2-Methylnaphthalene	20	ND	ND	ND	ND
Acenaphthylene	210	ND	ND	ND	ND
Anthracene	2,100	ND	ND	ND	ND
Benzo(a)anthracene	0.2	ND	ND	ND	ND
Benzo(b)fluoranthene	0.2	ND	ND	ND	ND
Benzo(k)fluoranthene	0.5	ND	ND	ND	ND
Benzo(g,h,i)perylene	210	ND	ND	ND	ND
Benzo(a)pyrene	0.2	ND	ND	ND	0.05
Chrysene	4.8	ND	0.050	ND	0.06
Dibenzo(a,h)anthracene	0.2	ND	ND	ND	0.10
Fluoranthene	280	ND	ND	ND	ND
Fluorene	280	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	0.2	ND	ND	ND	0.09
Phenanthrene	210	ND	ND	ND	ND
Naphthalene	20	ND	ND	ND	ND
Pyrene	210	ND	ND	ND	ND

[1] GCTLs as provided in Chapter 62-777, F.A.C.

USEPA = United States Environmental Protection Agency

Bold indicates an exceedance of action levels and/or GCTLs.

ND = Analyte was not detected.

TABLE 1-1 (CONTINUED)
SUMMARY OF ANALYTES DETECTED IN ADDITIONAL WELLS
SITE 1140NW
OUTLYING LANDING FIELD BRONSON
PENSACOLA, FLORIDA

Sample Location		Monitoring Well No. 6	Monitoring Well No. 11	Monitoring Well No. 12	Monitoring Well No. 13
Collect Date		6/6/2001	6/5/2001	6/6/2001	6/6/2001
	GCTLs [1] (µg/L)				
PAHs (USEPA Method SW-846 8310 µg/L)					
1-Methylnaphthalene	20	ND	ND	ND	14
2-Methylnaphthalene	20	ND	ND	ND	16
Acenaphthylene	210	ND	ND	ND	ND
Anthracene	2,100	0.060	ND	ND	ND
Benzo(a)anthracene	0.2	0.11	ND	ND	ND
Benzo(b)fluoranthene	0.2	0.11	ND	ND	ND
Benzo(k)fluoranthene	0.5	0.10	ND	ND	ND
Benzo(g,h,i)perylene	210	0.12	ND	ND	ND
Benzo(a)pyrene	0.2	0.090	ND	ND	ND
Chrysene	4.8	0.13	ND	ND	ND
Dibenzo(a,h)anthracene	0.2	ND	ND	ND	ND
Fluoranthene	280	ND	ND	ND	ND
Fluorene	280	ND	ND	ND	4.1
Indeno(1,2,3-cd)pyrene	0.2	0.090	ND	ND	ND
Phenanthrene	210	ND	ND	ND	1.6
Naphthalene	20	ND	ND	ND	12
Pyrene	210	0.19	ND	ND	ND

[1] GCTLs as provided in Chapter 62-777, F.A.C.

USEPA = United States Environmental Protection Agency

Bold indicates an exceedance of action levels and/or GCTLs.

ND = Analyte was not detected.

1.4 SCOPE AND GOALS

ISOC™ is a specially designed microporous mass transfer device invented and manufactured by inVentures Technologies, Inc. (iTi) for use in enhanced groundwater remediation. ISOC™ is based on iTi's proprietary Gas inFusion™ technology. The ISOC™ technology dissolves oxygen into liquids without bubbles through an ISOC™ diffuser. The ISOC diffuser looks similar to a stainless steel bladder pump from the outside and is 1.62 inches in diameter and 15 inches in length. The sizing is to allow the ISOC™ diffuser to be placed inside a 2-inch groundwater monitoring well. After an ISOC™ diffuser is placed into a monitoring well, the diffuser is connected to a tank with welding grade oxygen. The proprietary diffusion technology of ISOC™ allows dissolved oxygen (DO) concentrations of 50 to 70 parts per million in the groundwater. The increase in DO in the aquifer creates aerobic conditions that stimulate in-situ bioremediation of the petroleum hydrocarbon plume. Further information about ISOC™ Technology is provided in Appendices A and B.

During this treatability study, five ISOC™ diffusers will be installed in new monitoring wells (injection points) and oxygen will be injected into the area of impacted groundwater. The injection points will be located with the intention of providing a sufficient radius of influence (ROI) to saturate the groundwater in the contaminant plume.

A baseline sampling event and four quarters of groundwater sampling will be conducted from five selected monitoring wells. These wells will include the three wells that were sampled as part of the Monitored NA Plan, plus an upgradient well and a downgradient well. Quarterly performance monitoring letter reports will be prepared, and an annual performance monitoring report will be submitted after the first year of sampling. These sampling events and reports are explained in greater detail in Sections 2.0, 3.0 and 4.0 of this work plan.

The objective of the Treatability Study is to determine the effectiveness of ISOC™ technology at reducing the contaminant concentrations within the source area. This strategy is relying on consistently high DO levels to increase the microbial activity, thereby increasing contaminant reduction through aerobic respiration.

2.0 FIELD OPERATIONS

2.1 FIELD OPERATIONS SUMMARY

The pilot-scale study consists of the following field activities:

- Monitoring of the water level in monitoring wells MW-1 through MW-16.

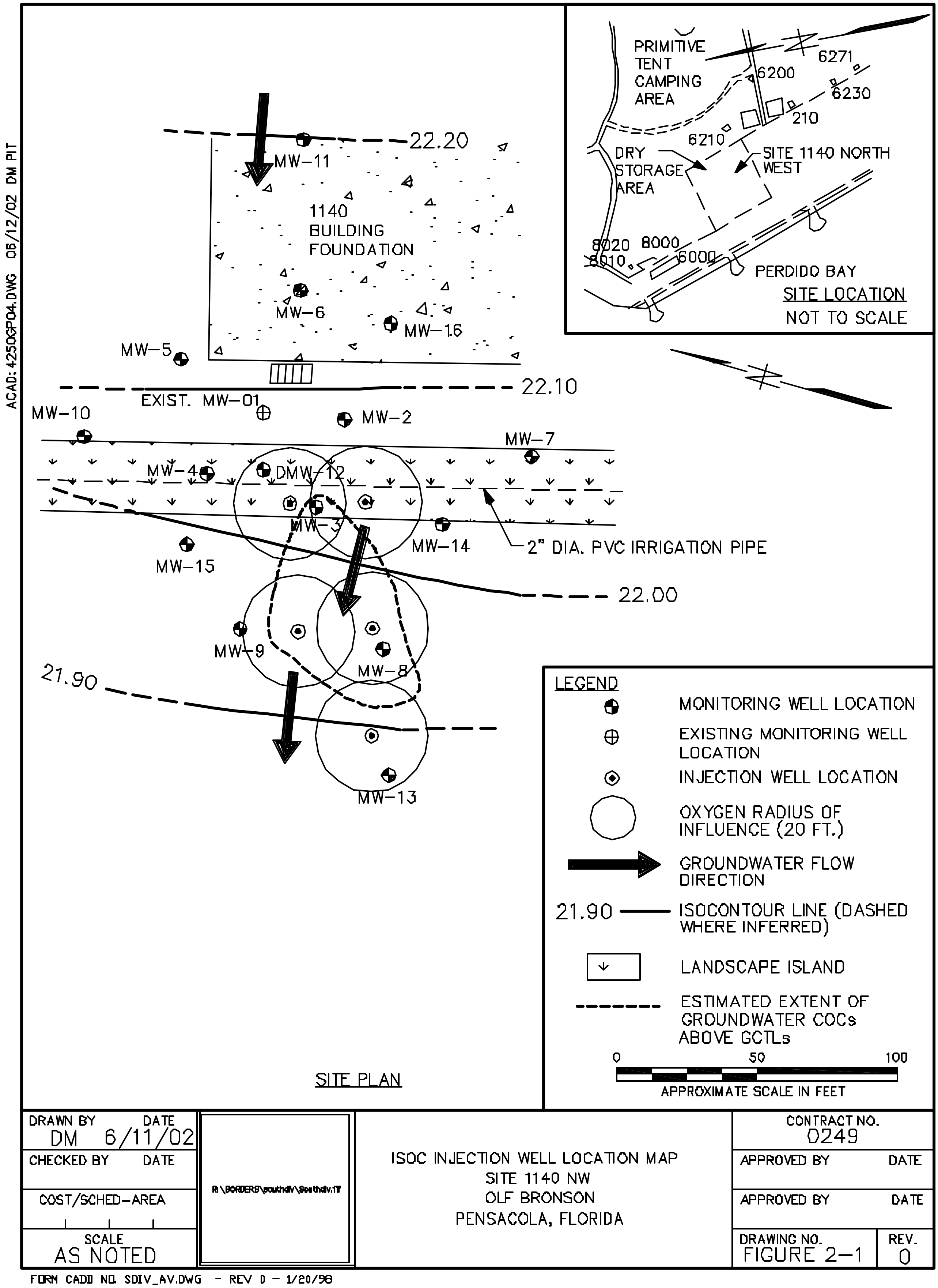
- Sampling and analysis of five selected monitoring wells (MW-2, MW-3, MW-8, MW-9, and MW-13) to evaluate baseline contaminant and geochemistry concentrations. Monitoring wells MW-3, MW-8 and MW-9 were part of the MOP. Monitoring well MW-2 will serve as an upgradient and background well and MW-13 will serve as a downgradient well.

- Installation of five permanent monitoring wells for injection points in the source area of the contaminant plume.

- Installation of five ISOC™ diffusers at each of the injection points.

- Quarterly sampling and analysis of the selected monitoring wells (MW-2, MW-3, MW-8, MW-9, MW-13) to evaluate water quality parameters and contaminant concentrations.

The pilot study will target the source area of the groundwater contaminant plume located at monitoring well MW-3, the midpoint area of the plume located upgradient of wells MW-8 and MW-9, and the downgradient area of the plume near MW-13. The Treatability Study involves the installation of five ISOC™ diffusers that will create zones of passive treatment, with a ROI of 15 to 20 feet (ft) as reported by iTi. The injection point locations and a ROI of 20 ft are shown on Figure 2-1. The cross sectional view of the injection well with the installed ISOC™ diffuser is presented as Figure 2-2. These injection wells are intended to create an oxygen-enriched area and an aerobic reaction zone to reduce petroleum hydrocarbon concentrations in site groundwater. The ISOC™ diffusers will be connected by polyethylene tubing to pressure gauges, a flow meter and oxygen tank located in a sub-grade manhole at each injection point. The site geochemistry will be monitored for changes in water quality parameters indicative of increased microbial activity along with laboratory analysis to indicate reductions in dissolved petroleum concentrations. Details of the sampling and analysis program are presented in Section 3.0.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PRIMITIVE TENT CAMPING AREA
6271
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DRY STORAGE AREA
SITE 1140 NORTH WEST
8020 8000
8010
6000
PERDIDO BAY
SITE LOCATION
NOT TO SCALE
22.20
MW-11
1140 BUILDING FOUNDATION
MW-6
MW-16
MW-5
22.10
EXIST. MW-01
MW-10
MW-2
MW-7
MW-4
DMW-12
MW-3
MW-14
2" DIA. PVC IRRIGATION PIPE
MW-15
22.00
MW-9
MW-8
21.90
MW-13
LEGEND
MONITORING WELL LOCATION
EXISTING MONITORING WELL LOCATION
INJECTION WELL LOCATION
OXYGEN RADIUS OF INFLUENCE (20 FT.)
GROUNDWATER FLOW DIRECTION
21.90
ISOCONTOUR LINE (DASHED WHERE INFERRED)
LANDSCAPE ISLAND
ESTIMATED EXTENT OF GROUNDWATER COCs ABOVE GCTLs
0
50
100
APPROXIMATE SCALE IN FEET
SITE PLAN
DRAWN BY DM
DATE 6/11/02
CHECKED BY
DATE
COST/SCHED-AREA
SCALE AS NOTED
ISOC INJECTION WELL LOCATION MAP
SITE 1140 NW
OLF BRONSON
PENSACOLA, FLORIDA
CONTRACT NO. 0249
APPROVED BY
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DATE
DRAWING NO. FIGURE 2-1
REV. 0
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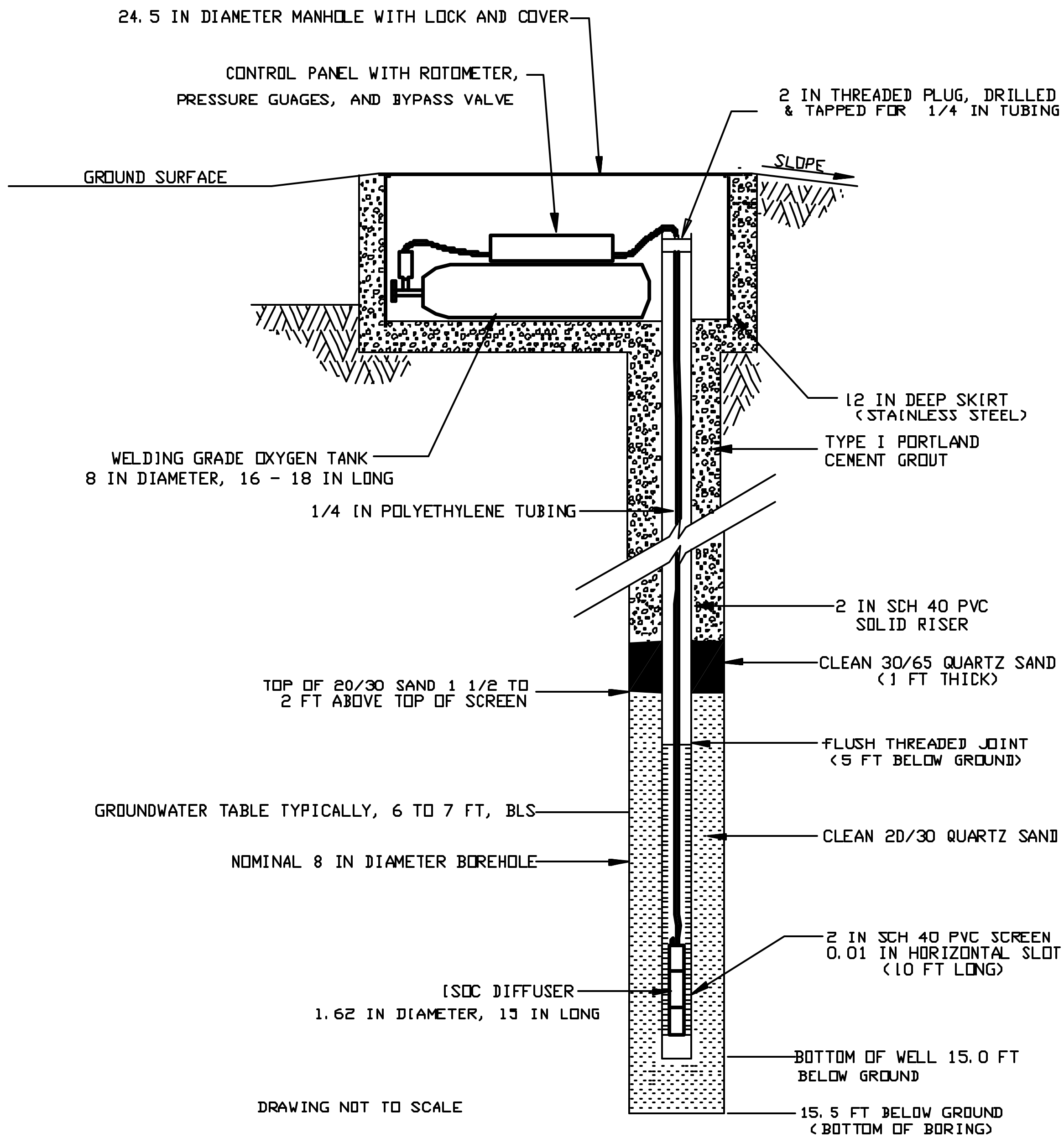

DRAWN BY JF DATE 5/28/02	INJECTION WELL CONSTRUCTION DETAIL TREATABILITY STUDY WORK PLAN SITE 1140NW OUTLYING LANDING FIELD BRONSON PENSACOLA, FLORIDA	CONTRACT NO. 0249
CHECKED BY DATE		APPROVED BY DATE
COST/SCHED-AREA		APPROVED BY DATE
SCALE AS NOTED		DRAWING NO. 2-2 REV. 0

2.2 MOBILIZATION/DEMOBILIZATION

Following approval of this work plan, TtNUS will procure the required subcontractors and begin mobilization activities. Mobilization/demobilization includes the following:

- Obtaining utility clearance for the site.
- Mobilizing required subcontractors, equipment and materials to the site.
- Obtaining necessary drilling and/or well permits, via the drilling subcontractor.
- Conducting an approximately 1-hour long site-specific health and safety review meeting.
- Delineating work zones (exclusion zone, contamination reduction zone, and support zone) as required by the Health and Safety Plan (HASP).
- Arranging an area to perform decontamination procedures.
- De-mobilizing equipment and materials from the site.
- Performing general site cleanup and removal of trash.

Field team members will review the work plan and the HASP. Mobilization includes attendance at a site-specific health and safety meeting during the initiation of on-site activities. This meeting will also include field team orientation in order to familiarize all personnel with the scope of the field activities.

The Field Operations Leader (FOL) will coordinate the mobilization activities. These include responsibilities such as: initiating and conducting equipment inventories to ensure equipment is available, purchasing equipment as required, staging equipment for efficient loading and transport from the TtNUS Jacksonville office to the site and, after field activities are completed, demobilizing the equipment.

The monitoring well installation subcontractor will furnish a truck-mounted drill rig, support crew, all necessary tools required, personal protective equipment (PPE) for their crew, and any miscellaneous equipment and materials required to complete the described activities. All down-hole equipment, sampling tools and the rear of the rig will be steam-cleaned prior to arrival on site. Safety shut-off equipment will be in full working condition and will be tested by the FOL prior to initiating drilling activities. The FOL will complete a Daily Activities Record (Appendix C) with the driller at the end of each workday.

2.3 INJECTION WELL INSTALLATION

Permanent shallow monitoring wells will be installed using hollow stem auger drilling techniques. The drilling subcontractor, prior to initiation of drilling activities at the site, will obtain well installation permits. The wells will be installed and constructed in general accordance with applicable guidelines from the following sources: Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells (SOUTHNAVFACENGCOM, 1997), and the Environmental Investigation Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), USEPA, 1996). Primary casing and screens of the monitoring wells will be constructed of 2-inch inside diameter, Schedule 40, flush-joint polyvinyl chloride riser and flush-joint 0.010-inch factory-slotted well screen. The monitoring well screen sections will be 10 ft in length. Shallow groundwater contamination is assumed to extend to approximately 13 ft below land surface (bls), based on the depth of the shallow monitoring wells previously installed at the site. Therefore, each of the injection wells will be installed to a depth of 15 ft bls and screened from 5 to 15 ft bls. The boring for each injection point will be terminated at 15.5 ft bls to provide approximately 0.5 ft of sand pack under each well.

The wells will be flush mounted and grouted with the 24½-inch bolt-down manhole covers. Manhole specifications are provided in Appendix D. The large manhole covers are required for the storage of the 18-inch long oxygen tanks, flow meter, and pressure gauges. The manhole covers provide a self-contained and lockable sub-grade treatment equipment storage area for each injection point, since Site 1140NW is in a public access area. The manhole cover is a 3/8-inch reinforced steel floor plate designed to sustain vehicular traffic. A diagram showing well construction design is presented as Figure 2-2. A boring log, monitoring well sheet, and certificate of conformance will be maintained for each well installation.

The monitoring wells will be developed no sooner than 24 hours after placement of grout to remove fine sediment from around the screened interval of the well. Field parameters [pH, temperature, turbidity, and specific conductance (SC)] will be measured at equally spaced time intervals during well development. Wells will be developed by pumping a maximum of one hour or until the field measurements become stable and the development water is visibly clear. Water quality stabilization will be determined using the following criteria:

- Temperature, plus or minus 0.5 degrees Celsius (ºC) over last three readings.
- pH, plus or minus 0.1 standard unit over last three readings.
- SC, plus or minus 10 percent of last three readings.

2.4 ISOC™ DIFFUSER INSTALLATION

The ISOC™ diffusers will be shipped from the iTi headquarters in Ottawa, Canada to the TtNUS Jacksonville, Florida office. iTi also provides a 10-inch x 12-inch individual control panel with the pressure gauges and rotometer pre-connected together for each diffuser. The control panel for each diffuser will also be shipped with the diffusers. Equipment necessary for the ISOC™ diffusers is specified in Appendix D. Prior to installation of the diffusers, the baseline groundwater-sampling event will be conducted at Site 1140NW. Once the baseline-sampling event has been conducted the installation of the

ISOC™ system will be performed. The following steps listed below provide information on the set-up of the system. Detailed installation instructions from the manufacturer are provided in Appendix D.

<u>Step 1:</u>

Determine the maximum (head) pressure to which the diffuser will be subjected. Use the following equation: *Head [pounds per square inch (psi)] = max water depth (ft) divided by 2.306*. Note that the maximum water depth is the depth to the top of the water column (i.e., static water level) not the depth of the well itself.

<u>Step 2:</u>

Connect the two-stage low-flow pressure regulator to the 40 cubic foot (ft^3) welding grade oxygen cylinder. **Note: the oxygen source must be welding grade oxygen**. Connect the pressure gauge/rotometer control panel to the low-flow regulator with the ¼-inch polyethylene tubing.

<u>Step 3:</u>

Connect the control panel to the ISOC™ diffuser with the ¼-inch polyethylene tubing. Note: a length of approximately 15 ft of tubing is necessary between the diffuser and the control panel. When connecting the tubing to the ISOC™ diffuser, be sure that the tubing is firmly pushed into the pushloc fitting on top of the ISOC™. Fasten a lifting wire to the lifting eye on top of the ISOC™ diffuser.

<u>Step 4:</u>

Lower the ISOC™ diffuser to the bottom of the well. Use the lifting line attachment for safe and easy insertion and removal. Place the oxygen cylinder, control panel, and excess tubing in the manhole.

<u>Step 5:</u>

With the bypass valve open, open the oxygen cylinder and adjust the regulator to 1 to 2 psi above the maximum head pressure and close the bypass valve.

<u>Step 6:</u>

Open the valve on the rotometer. Adjust the valve until the flow indicator "ball" reads between 60 to 80 on the scale. This is equivalent to 7 cubic centimeters per minute (cc/min) or 2.5×10^{-4} cubic feet per min (ft^3/min). It is not necessary that the 60 to 80 setting be maintained, but it is necessary to maintain the rotometer indicator ball "on scale" or mid-range.

<u>Step 7:</u>

Test fittings for leaks using leak detection solution or soap/water solution.

Step 8:

Place cover on manhole making sure to bolt down cover and lock. Install the four other ISOC™ diffusers at the injection well locations in the same manner.

Initial Monitoring of Unit

Although the ISOC™ diffuser is now functioning, it is necessary that the operation of the unit be monitored several times over the first few days to ensure proper operation. At the very low oxygen pressure and flow required by the diffuser, a series of adjustments over a few days following start-up is often needed to be sure that the regulator pressure has not dropped below the head pressure and that the rotometer reading is still on scale.

Relative to the volume of tubing in the system, the actual amount of gas flow is quite low. Systems such as these respond extremely slowly to small, downward adjustments of flow valves. It is easy to inadvertently turn the rotometer valve off and still have the rotometer ball register a flow for a period of time.

Changes in groundwater elevation in the well will affect the setup, requiring regular inspections and adjustments. If the oxygen feed rate has dropped to zero, and the DO reading in the well is below what is expected, the ISOC™ diffuser will have to be pulled from the well and drained. (See Troubleshooting Section.)

In order to prevent cessation of oxygen due to flooding, iTi recommends that a minimum gas flow of 1 to 2 cc/min be maintained at all times. This represents only 2 to 4 grams of oxygen per day. It should be noted that this small amount of “excess oxygen” will be released in the form of single large bubbles.

Troubleshooting

The unit will continue to operate as long as it is not deprived of oxygen. If it is, a vacuum in the ISOC™ diffuser can occur. This can result in water being drawn into the diffuser and reducing or stopping mass transfer. The two major causes are the regulator and the rotometer. A series of adjustments over a few days following startup is often needed to make sure that the regulator pressure has not dropped below the head pressure, and that the rotometer is still operating on scale. Sometimes it is necessary to “tap” the rotometer to make sure the ball is still reading on scale. It is not necessary that the rotometer be maintained at 60 to 80, only that it remain on scale at all times.

Should the ISOC™ diffuser be deprived of oxygen, pull it to the surface to drain any water from the infusion structure. Remove the drain plug and drain all water from the device. With the plug still removed, and the bypass valve open, set the regulator at 10 to 15 psi and blow out any water still remaining in the unit. This will take several minutes. Reinstall the plug. The unit is now ready for start-up.

2.5 WATER LEVEL MEASUREMENTS

During the baseline sampling event and the quarterly sampling events, groundwater level measurements will be obtained from Site 1140NW monitoring wells MW-1 through MW-16. During the quarterly sampling events, groundwater levels will also be obtained from the injection wells. These wells will be called 1140-INJ01, 1140-INJ02, 1140-INJ03, 1140-INJ04, and 1140-INJ05 and the FOL will designate them in the field. The synoptic measurements will be taken within a 2-hour period of consistent weather conditions to minimize atmospheric/precipitation effects on groundwater levels. Measurements will be taken with an electronic water level indicator or interface probe using the marked location on the top of the well casing as the reference point. Groundwater level measurements will be recorded to the nearest 0.01-ft on the appropriate field log. This information will be used to confirm groundwater flow direction.

2.6 INVESTIGATION-DERIVED WASTE (IDW) MANAGEMENT

All IDW accumulated during injection well installation, well purging and sampling, and decontamination proceedings will be collected, containerized, and stored in Department of Transportation (17C)/UN (1A2)-approved, 55-gallon drums. The drums will be labeled as soon as possible after they are filled. The drums will be left on site pending analytical results.

2.7 DECONTAMINATION

The field team's PPE will be disposed as required. These items, such as disposable latex gloves and paper towels will be temporarily stored in plastic bags with daily transfer to 55-gallon drums (with lids) at the end of each workday. Personnel will also perform decontamination procedures as required by the HASP before any departure from the site.

The equipment involved in field sampling activities will be decontaminated prior to and upon completion of drilling and sampling activities. This equipment includes drilling rigs, down-hole tools, augers, and all non-dedicated sampling equipment.

<u>Major Equipment</u>

All down-hole drilling equipment and sampling tools shall be decontaminated by the drilling crew prior to beginning work and at the completion of the injection well installation program. The decontamination procedures shall comply with the FDEP Standard Operating Procedures (SOPs).

Sampling Equipment

Sampling equipment used for collecting the groundwater samples will be disposable. Therefore, no decontamination of this equipment will be required. Field analytical equipment such as water level probes, and water quality meters will be first wiped down with lab-grade detergent solution, then rinsed with a isopropanol and analyte free water mix, and then with a final rinse of analyte free water.

3.0 ENVIRONMENTAL SAMPLING

3.1 SAMPLE ANALYSIS SUMMARY

Both field and laboratory measurements and analyses will be conducted in order to quantify any increase in the rate of microbial activity within the aerobic reaction zones, and to determine the contaminant reduction rates.

3.1.1 Laboratory Sample Analysis Summary

A certified laboratory will be subcontracted by TtNUS to perform the routine chemical analyses for the environmental samples collected for Site 1140NW during the treatability study.

The laboratory analytical methods, bottle requirements, preservation requirements, and holding times are as follows:

Laboratory Groundwater Analyses

Parameter	Analytical Method	Bottle/Preservation Requirements	Holding Time
PAHs	SW 846 8310	Two one-liter amber jars Cool to 4°C	14 days to analysis
Total Organic Carbon (TOC)	USEPA 415.1	One 250ml High Density Polyethylene (HDPE) Sulfuric Acid (H_2SO_4)<2; Cool to 4°C	28 days to analysis
Sulfate	USEPA 300	One 250ml HDPE; Cool to 4°C	28 days to analysis

Laboratory Soil Analyses (for disposed of soil generated during drilling)

Parameter	Analytical Method	Bottle/Preservation Requirements	Holding Time
Resource Conservation and Recovery Act (RCRA) 8 Metals	USEPA 6010B	One 4-ounce clear wide mouth (cwm) jar. Cool to 4°C	28 days to analysis
PAHs	SW 846 USEPA 8310	One 4-ounce cwm jar. Cool to 4°C	7 days to analysis
TRPH	Florida Petroleum Range Organics (FL-PRO)	One 4-ounce cwm jar. Cool to 4°C	7 days to analysis
Volatile organic compounds (VOCs)	SW 846 USEPA 8260B	3 Encore samplers. Cool to 4°C	14 days to analysis

3.1.2 Field Analysis Summary

Field geochemical analyses will be performed during field sampling activities on the five selected monitoring wells for the parameters specified in the following table:

Field Analyses

Parameter	Analytical Method	Holding Time	Analyze
DO (range 0 to 50 ppm)	YSI 556 MPS Water Quality Meter	Analyze immediately	Field
Temperature	YSI 556 MPS Water Quality Meter	Analyze immediately	Field
pH	YSI 556 MPS Water Quality Meter	Analyze immediately	Field
Conductivity	YSI 556 MPS Water Quality Meter	Analyze immediately	Field
Turbidity	YSI 556 MPS Water Quality Meter	Analyze immediately	Field
Carbon Dioxide	CHEMetrics K-1910/1920/1925	Analyze immediately	Field
Alkalinity	CHEMetrics K-9810/9815/9820	Analyze immediately	Field
Ferrous Iron	HACH IR-18C	Analyze immediately	Field
Hydrogen Sulfide	HACH HS-C	Analyze immediately	Field
Oxidation Reduction Potential (ORP)	YSI 556 MPS Water Quality Meter	Analyze immediately	Field

3.2 GROUNDWATER SAMPLING PROCEDURES

Groundwater samples will be obtained from the five selected groundwater monitoring wells (MW-2, MW-3, MW-8, MW-9, and MW-13) during the baseline and four quarterly sampling events. Samples will be collected quarterly for the above laboratory groundwater analyses and reference field analytical tests. DO readings will also be obtained from the five injection wells (1140-INJ01, INJ02, INJ03, INJ04, and INJ05) and monitoring wells MW-14 and MW-15 during the quarterly sampling events. Work at Site 1140NW will be conducted under the Comprehensive Quality Assurance Plan (CompQAP) provisions since this site predates the new Florida SOPs.

Prior to obtaining samples, water levels will be measured and the wells will be purged using a low-flow peristaltic pump. A minimum of three well volumes will be purged prior to sample collection. If the wells are purged dry with less than three well volumes removed, the water level in the well will be allowed to recover to at least 80 percent of the original capacity prior to sampling. During well purging, field measurements of pH, temperature, SC, turbidity, ORP, and DO will be recorded for each well volume. Stabilization is defined as follows: temperature ±1°C; pH ±0.1 standard units, and SC ±10 percent. If these parameters do not stabilize after three volumes, up to five volumes may be removed as determined by the FOL.

Teflon and surgical-grade silicon tubing will be used for sample collection. Groundwater samples for PAH analysis will be collected using the purge and trap method and discharged into the appropriate sample bottles for analysis. Samples requiring preservation will be collected in pre-preserved bottles provided by the laboratory.

Pertinent sampling data will be recorded using the appropriate sample log sheet and field logbook (see Appendix C for forms to be used during the Treatability Study).

3.2.1 Operation and Maintenance (O&M) of ISOC™ Diffusers

The ISOC™ diffusers and related equipment require minimal O&M. O&M of the ISOC™ system will be performed during groundwater sampling activities. O&M activities will consist of the following:

- Check and replace the oxygen tanks at each injection well on a quarterly basis if necessary. According to iTi, a 40 ft^3 tank will last three to four months for one ISOC™ diffuser. The tanks will be checked to determine remaining oxygen and replaced as necessary.

- Record rotometer readings at each injection well and adjust to mid-range if necessary. If oxygen flow is zero, refer to troubleshooting section.

- Measure depth to water at each injection well and record. If the water table has risen since the last monitoring event, reset low flow regulator to head pressure specified in Section 2.4.

- Check tubing and connections on each injection system to make sure that no leaks have developed.

- Measure DO readings in each injection well and record. If DO readings are low, refer to trouble shooting section.

- Secure manhole covers after O&M activities are completed.

3.3 SAMPLE HANDLING

Sample handling including the field-related considerations concerning sample identification, packaging and shipping will be addressed throughout this section.

3.3.1 Sampling Identification System

Each sample collected will be assigned a unique sample tracking number. The sample tracking number will consist of a four-segment, alphanumeric code that identifies the site, sample location, and sample round. The samples collected from the most recent sampling event were designated as the first (01) sample round. Therefore, the baseline-sampling event through the quarterly sampling rounds for the Treatability Study will be designated as the second through sixth rounds. Pertinent information regarding sample identification will be recorded in the field logbooks.

The appropriate alphanumeric sample identification code is explained as follows:

(Site Location) (Site) (Sample Number) (Sample round)

Site Location: Outlying Landing Field Bronson (OLFB)

Site: Site 1140NW (1140)

Sample Number:

Groundwater sample = well number (e.g., M03 for MW-3, M08 for MW-8, and M13 for MW-13). For duplicate samples the sample number will be the alphanumeric Dx, where D does not change and x is a number beginning at 1 and progressing for each subsequent duplicate sample (e.g., D1, D2, and D3).

Sample Round:

For groundwater samples = designated sample round number (e.g., 02, 03, 04, 05, and 06)

For example, a groundwater sample collected from monitoring well MW-3 during the baseline sampling before the ISOC™ Treatability Study will be designated as follows:

OLFB-1140M0302

A duplicate of the listed above would be as follows:

OLFB-1140D0102

3.3.2 Sample Packaging and Shipping

The FOL will be responsible for completion of the following forms:

- Sample Labels
- Chain-of-Custody Forms
- Appropriate labels applied to shipping coolers
- Chain-of-Custody Seals
- Federal Express Air Bills

All samples will be packaged and shipped in accordance with TtNUS's FDEP approved CompQAP last updated August 25, 1999, Revision 1.

3.4 SAMPLE CUSTODY

Custody of samples must be maintained and documented at all times. Chain-of-custody begins with the collection of the samples in the field. TtNUS SOP SA-6.3 provides a description of the chain-of-custody procedures to be followed.

3.5 QUALITY CONTROL (QC) SAMPLES

Work at Site 1140NW will be conducted under the CompQAP provisions since this site predates the new Florida SOPs. In addition to regular calibration of field equipment and appropriate documentation, minimal QC samples will be collected during the treatability study sampling activities, since dedicated and/or disposable equipment is to be used for sampling. One field duplicate sample will be collected during each sampling event. No other QC samples are proposed.

Field duplicates for groundwater are defined as two samples collected independently at a sampling location. Duplicates are obtained during a single act of sampling and are used to assess the overall precision of the sampling and analysis program. Ten percent of all environmental samples are required by the FDEP SOPs to be duplicated. Duplicates will be analyzed for the same parameters as the original sample.

3.6 EQUIPMENT CALIBRATION

Several monitoring instruments may be used during field activities. These include the following:

- Photoionization or flame ionization detector
- YSI 556 MPS water quality meter/probe
- Electronic water-level meter

Calibration will be documented on an Equipment Calibration Log (Appendix C). During calibration, an appropriate maintenance check will be performed on each piece of equipment. If damaged or defective parts are identified during the maintenance check and it is determined that the damage could have an impact on the instrument's performance, the instrument will be removed from service until the defective parts are repaired or replaced.

3.7 EQUIPMENT MAINTENANCE

Measuring equipment used in environmental monitoring or analysis and test equipment used for calibration and maintenance shall be maintained by established procedures.

TtNUS maintains an inventory of sampling and measurement equipment. In the event that failed equipment cannot be repaired, replacement equipment will be shipped to the site by overnight carrier to minimize downtime.

3.8 RECORD KEEPING

In addition to chain-of-custody records, certain standard forms will be completed for sample description and documentation. These forms shall include sample log sheets, boring logs, well completion diagrams, daily record of subsurface investigation reports, and logbooks. Field documentation and example field log forms are provided in Appendix C.

A bound/weatherproof site logbook will be maintained by the FOL. All information related to sampling or field activities will be recorded in the site logbook. This information will include, but is not limited to, sampling time, weather conditions, unusual events, field measurements, descriptions of photographs, etc.

4.0 PROJECT MANAGEMENT

The management and technical aspects of this project are the ultimate responsibility of TtNUS. Each contractor assigned to individual tasks has the responsibility to fulfill the objectives of that task and to ensure the quality of the data generated by the task. At the direction of the Navy, TtNUS has overall responsibility for the investigations to be performed at Site 1140NW.

4.1 PROJECT ORGANIZATION

The various QA and management responsibilities of key TtNUS project personnel are defined in the following paragraphs.

<u>CLEAN Program Manager</u> - The TtNUS Program Manager is responsible for the execution of all contractual obligations. The Program Manager serves as the primary point of contact for the client and provides an interface between the Navy and the project staff. The TtNUS CLEAN Program Manager is Ms. Debbie Wroblewski.

<u>CLEAN Project Manager</u> - The Project Manager is responsible for project performance, budget, and schedule, and for ensuring the availability of necessary personnel, equipment, subcontractors, and services. He/she will direct the development of the field program, evaluation of findings, determination of conclusions and recommendations, and preparation of technical reports. The TtNUS Project Manager for CTO 0249 is Mr. Gerald Walker, P.G.

<u>FOL</u> - The FOL, responsible for providing on-site supervision of day-to-day activities on the project. The FOL serves as the primary on-site contact with the client and subcontractors. In addition, the FOL is responsible for all field QA/QC and safety-related issues as defined in the HASP. The FOL for this project will be designated prior to the start of field operations by the Project Manager.

<u>Health and Safety Manager (HSM)</u> - The Program HSM will review and internally approve the HASP tailored to the specific needs of the investigation. In consultation with the Project Manager/FOL, the HSM will ensure that an adequate level of personal protection exists for anticipated potential hazards for all field personnel. As the HSM does not report to either the Program or Project Manager, his/her actions are not dictated by program or project constraints (such as budget and schedule) other than the assurance of appropriate safeguards while conducting investigation activities. The TtNUS HSM is Mr. Matthew Soltis, Certified Industrial Hygienist (CIH).

QA Manager/Sampling Coordinators - The Project Manager/FOL will coordinate the schedule of field sampling activities with the schedule and capacity requirements of the selected analytical laboratory. All sampling will be coordinated to assure that environmental sampling is conducted in a manner that complies with all QA/QC requirements and is in compliance with holding time and analytical procedure requirements. All program-wide, QA issues are the responsibility of the QA Manager. The TtNUS QA Manager for Navy CLEAN activities is Mr. Paul Frank.

Project Laboratory – The project laboratory has not been selected at this time.

4.2 PROJECT RESPONSIBILITIES

Throughout the field activities, TtNUS personnel will provide and/or coordinate with the appropriate vendors the following various support functions:

- Locate and mark underground utilities and issue digging or other required permits prior to the commencement of digging or drilling operations.

- Take custody of all drill cuttings, well development fluids, decontamination fluids, or drill cuttings.

- Secure staging areas for decontamination operations and for storing equipment and supplies. It is anticipated that access can be gained to Site 1140NW.

- A supply of electricity and potable water for equipment cleaning, etc.

4.3 CONTINGENCY PLAN

In the event of problems that may be encountered during the site investigation activities, the TtNUS Project Manager will notify the Navy Remedial Project Manager (RPM) and Naval Air Station (NAS) Pensacola Point of Contact. The Project Manager will determine a course of action so as to minimize impacts to the project schedule and/or budget. Contingency plans will be approved through the Navy RPM before being enacted.

4.4 REPORTING

During performance of the ISOC™ treatability study, TtNUS will prepare the following reports:

Baseline Monitoring and ISOC™ Installation Report

Upon completion of the baseline sampling event and the installation of the ISOC™ diffuser system, TtNUS will prepare the Baseline Monitoring and ISOC™ Installation Report, which will include the following:

- The results of the pre-installation sampling and ISOC™ installation activities.
- The ISOC™ installation procedures, drilling logs, and any other data developed as part of the pilot-scale field activities.
- The groundwater sampling procedures and sample results.
- The groundwater flow conditions.
- Any other data collected during the sampling event.

This Baseline Monitoring Report will be prepared in draft form for SOUTHNAVFACENGCOM review and final form to be submitted to the FDEP.

First, Second and Third Quarterly Performance Monitoring Results Transmittal Letters

Upon completion of the first, second, and third quarters of performance monitoring, TtNUS will prepare a brief letter report presenting the sample results.

Treatability Study Evaluation Report

Upon completion of the fourth quarter of performance monitoring, TtNUS will prepare a Treatability Study Evaluation Report discussing the groundwater sampling procedures, and presenting a summary and comparison of all four-quarters of sample results. The report will present information on the groundwater flow conditions and any other data collected during the Treatability Study. In addition, the report will present conclusions and recommendations for future remedial action at the site, if any. The Treatability Study Evaluation Report will be prepared in draft form for SOUTHNAVFACENGCOM and NAS Pensacola review and in final form for SOUTHNAVFACENGCOM and the FDEP.

REFERENCES

NPWC (Navy Public Works Center), 1998. Contamination Assessment Report Addendum, 1140 NW Site, Outlying Landing Field Bronson, Naval Air Station Pensacola, Pensacola, Florida, November.

SOUTHNAVFACENGCOM (Southern Division, Naval Facilities Engineering Command), 1997 (revised). Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells.

TtNUS (Tetra Tech NUS, Inc.), 2000a. Letter Report: Resampling of Monitoring Wells MW-3 and MW-6, Site 1140 NW, Outlying Landing Field Bronson, Pensacola, Florida, February.

TtNUS, 2000b. Initial Semi-annual Monitoring for Natural Attenuation Letter Report: Site 1140NW, Outlying Landing Field Bronson, Pensacola, Florida, August.

TtNUS, 2001. Letter Report: Supplemental Site Assessment Sampling Site 1140NW, Outlying Landing Field Bronson, Pensacola, Florida, September.

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APPENDIX A

ISOC™ USER GUIDE

inVentures Technologies incorporated

Creating Value Through inNovation

Fredericton • Oakville • Ottawa

iSOC™ User Guide

iSOC™ Groundwater Oxygenation System

in situ Submerged Oxygen Curtain: another innovation from iTi's patented *Gas inFusion*™ mass transfer Technology—'elegance in simplicity'

United States Patent 6,209,855

Contact for Sales & Service:

Performance Technologies

Advanced Environmental Solutions

Performance Technologies, Inc. • 337 Hunters Crossing • Tallahassee, FL USA 32312 • Tel: 850-385-7790 • Fax: 850-894-1067
Email: donrayoffice@home.com

User Guide: v.iTi.soc.ug.pt.01.03

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iSOC™ User Guide

Introduction

iSOC™ is a specially designed, highly structured, microporous mass transfer device invented and manufactured by inVentures Technologies incorporated (iTi) for use in enhanced groundwater remediation. *iSOC*™, or in situ Submerged Oxygen Curtain, is based on iTi's proprietary *Gas inFusion*™ technology, which is patented worldwide. Its inherently large surface area allows for intimate contact between oxygen and groundwater, resulting in ultra efficient mass transfer.

This user guide provides background information on how the *iSOC*™ works, what you can expect from it in performance, how to install and start it up, and how to troubleshoot its operation.

Oxygenation of Water 101

Dissolving a gas into a liquid is a 'mass transfer' operation. Mass transfer requires two things to occur:

1. First, there must be a 'driving force'. The driving force in a gas/liquid system is the difference between the amount of gas currently in the liquid, and the maximum amount of gas that that liquid can hold, or take into solution, also known as the solubility. The solubility of a gas in a liquid is governed by Henry's Law and is unique to each gas/liquid system.

2. Second, there must be a means or pathway for the gas molecules to contact the liquid stream. This is also known as 'interfacial surface area'.

__Henry's Law__ states: The weight of any gas that will dissolve in a given volume of liquid, at constant temperature, is directly proportional to the pressure that the gas exerts above the liquid.

In equation form: $C_{equil} = \alpha\, p_{gas}$

where:

C_{equil} is the concentration of gas dissolved in the liquid at equilibrium;
p_{gas} is the partial pressure of the gas above the liquid; and
α is the Henry's Law constant for the gas at the given temperature.

Conventional methods of oxygenation of water, as illustrated in Figure 1, are energy intensive processes. This is due to the fact that oxygen is only sparingly soluble in water. The solubility of atmospheric oxygen in water ranges from about 15 ppm (mg/l) at 0°C to about 7 ppm at 35°C under 1 atmosphere of pressure. Most of the critical conditions related to dissolved oxygen deficiency in biological operations, including bioremediation, occur during the summer months when temperatures are higher and solubility of oxygen is at a minimum. For this reason, it is customary to think of dissolved oxygen levels of about 6 to 8 ppm being the maximum available under critical conditions.

Because of this low solubility, there is very little 'driving force'. In order to accomplish any mass transfer on a reasonable time scale, energy is expended to create interfacial surface area. Fine bubble diffusers, or chemical oxygen production compounds, release oxygen in the form of bubbles, usually in the range of 1 to 2 mm in diameter. These small bubbles create the interfacial surface area required for mass transfer.

Despite their small size, the vast majority of the oxygen (90 to 95%) created by these methods escapes from the water surface into the atmosphere. This escaping oxygen represents a high proportion of wasted energy and wasted money.

Figure 1: Conventional Oxygenation

For example, the supply of oxygen to suspended biomass in wastewater treatment represents the largest single energy consumer in an activated sludge treatment facility. Recent studies indicate that the aeration system accounts for 50% to 90% of the total power demand. According to industry experts, only about 1% of all oxygen discharged from a fine bubble diffuser is absorbed per foot of tank depth. In a 10-foot deep tank, 90% of the applied oxygen escapes to the atmosphere. Along with the escaped oxygen and air are the noxious odors and VOC's that often require scrubbing at further energy cost.

In any biological treatment process, the limited solubility of oxygen is of great importance because it governs the rate at which oxygen will be absorbed by the medium and therefore the cost of oxygenation.

Before we discuss how *Gas inFusion™* differs from these conventional means of oxygenation, we need to address the concept of how much dissolved gas a liquid can 'hold'. Earlier we described 'solubility' as the maximum amount of gas a liquid can take into solution. This level of dissolved gas 'saturation' is also used extensively and is defined conventionally.

Saturation is defined as:

I. The condition of a liquid when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.

Supersaturation is conventionally defined as:

I. An unstable condition of a vapor in which its density is greater than that normally in equilibrium under the given conditions; or

II. An unstable condition of a solution in which it contains a solute at a concentration exceeding saturation.

Obviously, 'supersaturation' is an unstable condition and not in equilibrium. Now, let's look at why *Gas inFusion™* redefines the concept of 'supersaturation' or more accurately,

Gas inFusion™ Intro

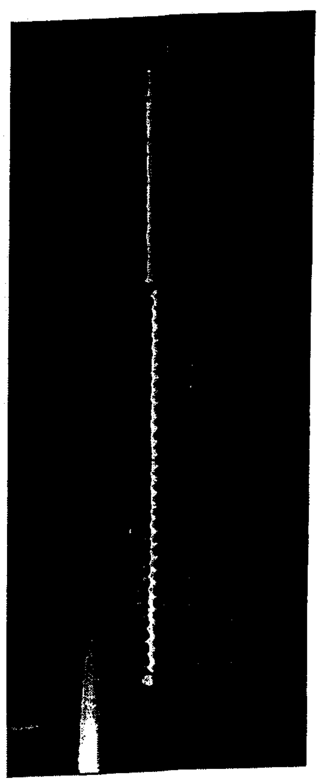


Figure 3: *iSOC™* 70 ppm DO

Gas inFusion™ is a proprietary technology (patented worldwide) developed by inVentures Technologies incorporated (iTi) for dissolving gas into liquids **without bubbles**. Figure 3 illustrates an *iSOC™* unit connected to a standard oxygen cylinder and suspended in a clear, open top column. Although this *iSOC™* is actively oxygenating the water in the column to a concentration of 70 ppm dissolved oxygen, there are no bubbles.

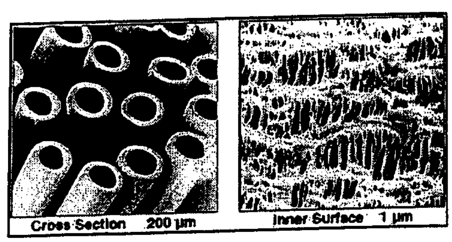


Figure 2: Microporous Hollow Fibre

Microporous hollow fibre, illustrated in Figure 2, is employed to provide the interfacial area needed to accomplish efficient mass transfer. The fibre provides an enormous surface area for mass transfer—in excess of 7000 m^2 per m^3—and is hydrophobic. This means that water will not pass through the pores of the fibre. Gas, on the other hand, fills the pores of the fibre. Maintaining a gas pressure less than the liquid pressure ensures that ultra efficient mass transfer takes place without a bulk passage of gas into the liquid. Bulk transfer of gas creates bubbles. ***Gas inFusion™* is mass transfer without bubbles.**

Henry's Law still governs the 'driving force' for this mass transfer. Increasing the pressure of the system raises the solubility of the gas and allows for greater levels of dissolved oxygen to be achieved.

Supersaturation, as created by *Gas inFusion™*, differs significantly from conventional conditions, and the conventional definition described above, as it achieves dissolved oxygen concentrations of hundreds of ppm in water in a relatively stable condition. Rather than escaping from the water surface, *Gas inFusion™* supersaturation creates a 'nascent' supply of dissolved oxygen that remains in a dissolved state until utilized by a biomass. The decay of even very high dissolved oxygen concentrations in the hundreds of ppm has been demonstrated to be several days. Obviously, this unique method of water oxygenation becomes ultra efficient in both biomass utilization and energy savings.

iSOC™ Intro

iSOC™ is a specially designed, highly structured, microporous mass transfer device invented and manufactured by inVentures Technologies incorporated (iTi) for use in enhanced groundwater remediation. *iSOC™*, or in situ Submerged Oxygen Curtain, is based on iTi's proprietary *Gas inFusion™* technology. Its inherently large surface area allows for intimate contact between oxygen and groundwater, resulting in ultra efficient mass transfer.

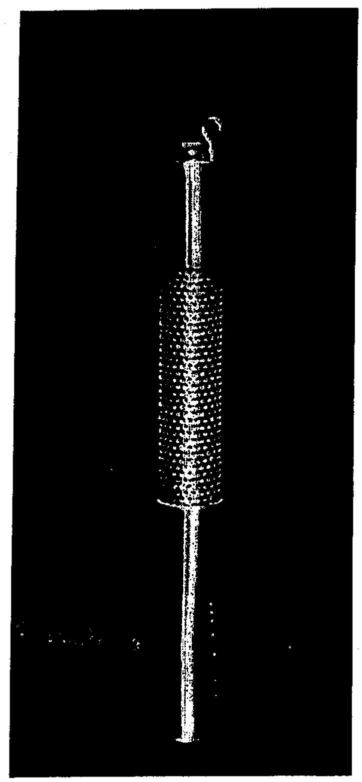


Figure 4: iSOC™ Unit

The *iSOC™* unit, illustrated in Figure 4, is made of stainless steel and is 1.62 inches in diameter and about 15 inches in length. The sizing is to allow the *iSOC™* to be placed inside 2 inch diameter groundwater monitoring wells.

The top of the unit is equipped with a 'push-loc' fitting to accommodate the ¼ inch diameter Polyflow tubing used to connect the unit to a source of pressurized oxygen, usually a liquid oxygen cylinder. Although the tubing and fitting will support a considerable tensile strength, a 'lifting eye' is also installed on the top of the unit. A wire may be attached to this eye to enable removal from the well if the tubing or push-loc fitting is broken.

The center part of the unit, with the holes, is the area from which the oxygen is 'infused' into the groundwater.

The bottom section of the *iSOC™* unit drains and collects any water which may occur in the infusion section due to improper operating conditions. The drain fitting on the bottom allows this water to be drained and the unit to be 'blown' clear.

iSOC™ Performance

Due to the enormous surface area presented by the *iSOC*™ device, an oxygen saturated zone is quickly established around the device at the bottom of the groundwater well. The actual oxygen content achieved through use of the *iSOC*™ is governed by the depth of water/gas pressure on the unit. Remember Henry's Law discussed earlier?

This saturated zone spreads up and throughout the well, and diffuses out of the well. Higher in the well, the head pressure begins to fall. This results in water that is no longer saturated, but is now **supersaturated**. As defined previously, conventionally produced supersaturation is unstable and effectively unattainable. However with *Gas inFusion*™, the release of oxygen from this supersaturated state is such an extremely slow process, from such a high dissolved concentration, that a relatively stable supersaturated state is created. This is especially true in the absence of other bubbles. An excess of bubbles actually works to strip out dissolved gas from a liquid, as bubbles tend to grow on bubbles.

Anything in nature is always working toward an equilibrium state. The supersaturation 'half-life', i.e., the time required for the level of saturation between normal solubility and this ultra-high level of *Gas inFusion*™ supersaturation to be reduced by one-half, was demonstrated to be up to 7 days in a 10' by 2" column. This results in a '**nascent**' supply of oxygen that is readily transferred to lower dissolved oxygen groundwater entering the well zone, or that is consumed for biological treatment by biomass.

As a function of the groundwater flow rate, the graph illustrated in Figure 5 indicates the expected dissolved oxygen concentrations that each groundwater well equipped with an *iSOC*™ can be expected to reach. This example assumes the water depth to be 10 feet with the *iSOC*™ located at the bottom of the well. Obviously, as the groundwater flow rate increases to very high levels, the achievable dissolved oxygen concentration is reduced.

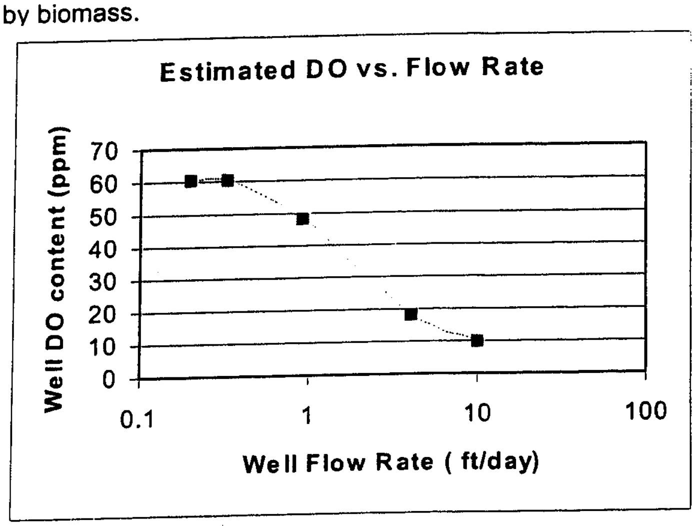


Figure 5: Estimated *iSOC*™ DO vs. Flow Rate

Due to a natural mixing effect of the oxygenated water in the groundwater well, the dissolved oxygen concentrations should be relatively equal throughout the depth of the well. Once the *iSOC*™ is first installed in a well, it takes a little while for the dissolved oxygen concentration to build up to maximum levels. Figures 6 and 7 illustrate a short duration test of some 100 hours, recording the dissolved oxygen concentration at various depths in a well over time from start up. Figure 6 shows a log time scale to indicate that it took about 16 hours (~1000 minutes) for the *iSOC*™ to maximize the dissolved oxygen concentration in the well to 35 ppm. Figure 7, with a conventional time scale, illustrates that once the maximum oxygen level was attained, it remained relatively constant over time. Also, note that the oxygen concentrations at 1-foot intervals were roughly the same.

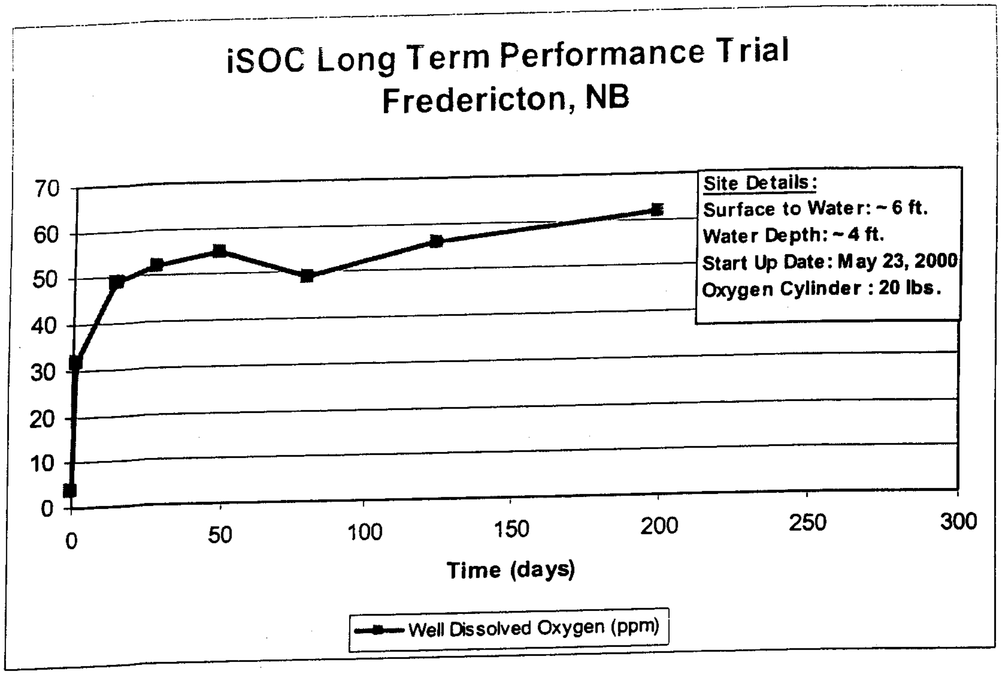


Figure 8: ***iSOC™*** **Long Term Performance Trial**

iSOC™ Long Term Performance

iSOC™ provides a low maintenance, low cost solution to the oxygenation of groundwater for remediation purposes. Once set up according to recommended procedures (See Equipment Set Up and Installation & Start Up Procedures), *iSOC™* continues to perform with only a periodic check.

Figure 8 illustrates the results of an ongoing long-term performance trial. As shown, this *iSOC™* unit, installed on May 23, 2000, continues to generate 50 to 60 ppm of DO in 4 feet of groundwater at a 10 foot depth over the charted 7 months and continues to date. The unit has never been removed from the well, nor has it required any adjustment following initial set up.

This trial clearly demonstrates the reliability and low maintenance of *iSOC™*—based on a technology that is elegantly simple.

Equipment Set Up

iSOC™ is a passive groundwater *Gas inFusion*™ device manufactured by iTi. The actual groundwater remediation system design and specification incorporating *iSOC*™ devices is the responsibility of the remediation consultant.

Figure 9 illustrates a typical schematic for equipment setup for use of an *iSOC*™. For best results, the oxygen cylinder should be equipped with a two-stage, **low-flow** pressure regulator, such as an Air Liquide Blueshield BLU-104 **oxygen** regulator. In order to maintain accurate control over the very low oxygen flows, a **low-flow** rotameter (flow meter) such as Cole Parmer Model 03217-00, or Dwyer Model RMA-151-SSV, should be connected in series between the *iSOC*™ unit and the pressure regulator. The rotameter should be equipped with a fine control needle valve. For convenience, it is also recommended that a ¼ inch bypass valve be installed parallel to the rotameter (See Figure 9). To ensure proper operation, the flow rotameter must deliver oxygen from a pressurized source (cylinder) at reliable, controllable rates of less than 10 cc/min. The flow rate must be stable on a continuous basis.

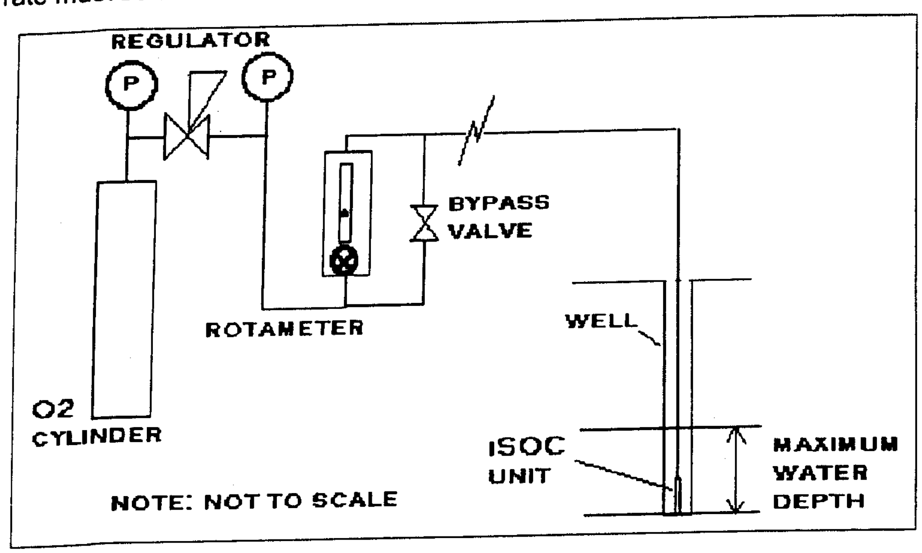
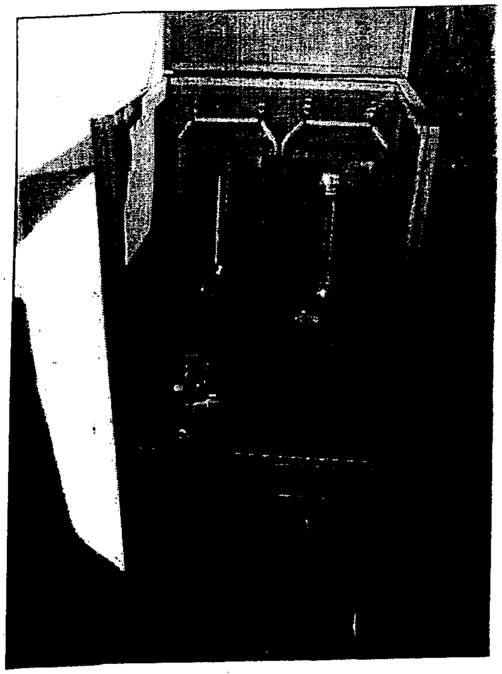


Figure 9: *iSOC*™ Equipment Setup Schematic

The actual equipment setup design and specification varies with site conditions, number of *iSOC*™s employed, and the preference of the consultant and/or client. Figures 10 to 15 illustrate different approaches to equipment layout and installation used in groundwater remediation systems based on *iSOC*™.



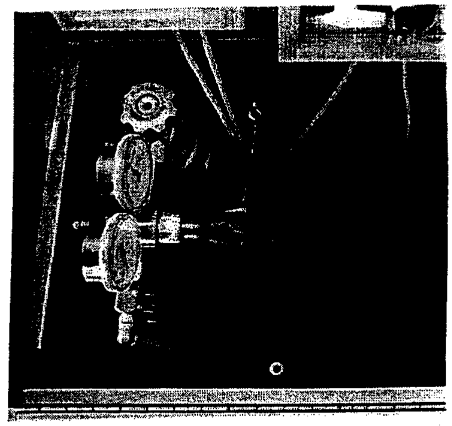


Figure 10: Example *iSOC*™ O_2 Equipment Installation

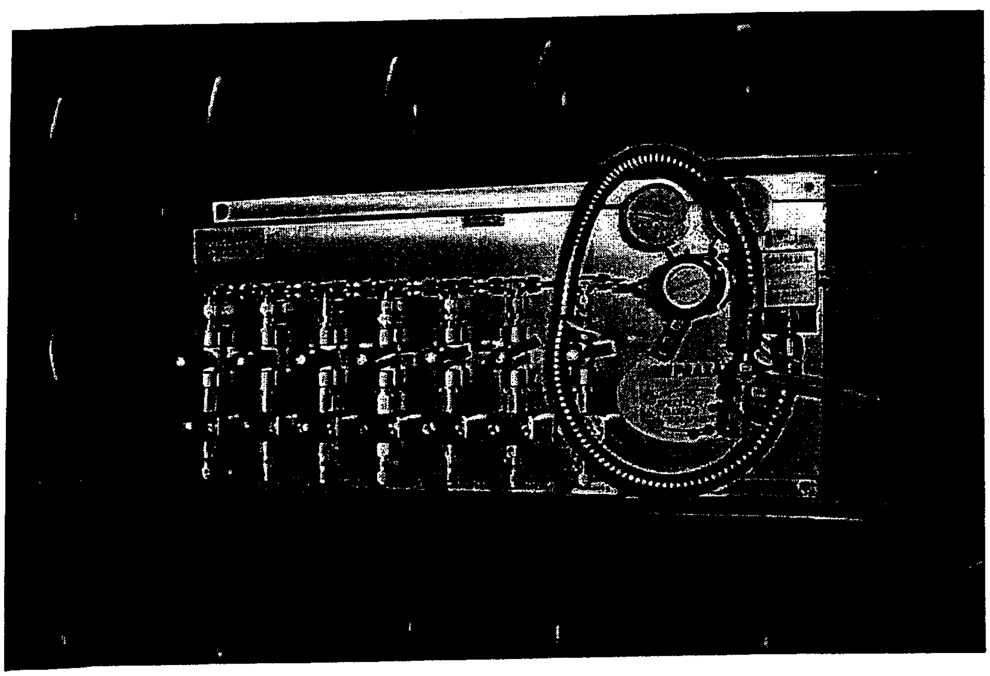
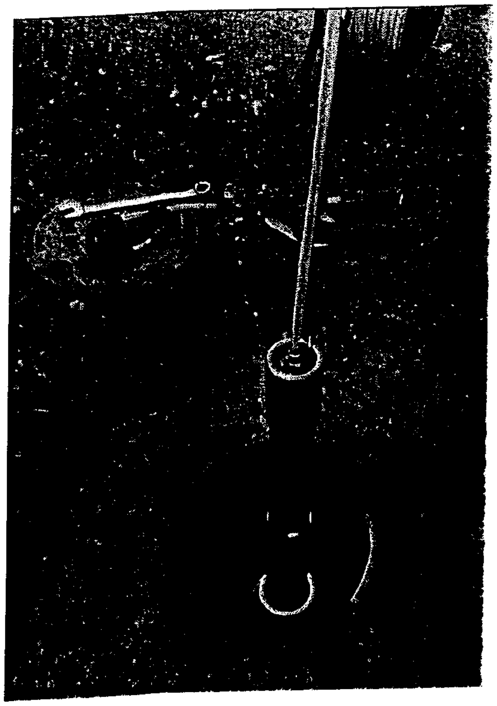


Figure 11: Example Multiple *iSOC*™ O_2 Distribution Panel



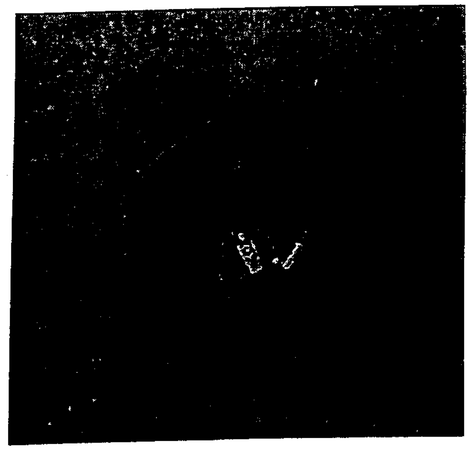


Figure 12: Example *iSOC*™ Well Insertion & Wellhead Details

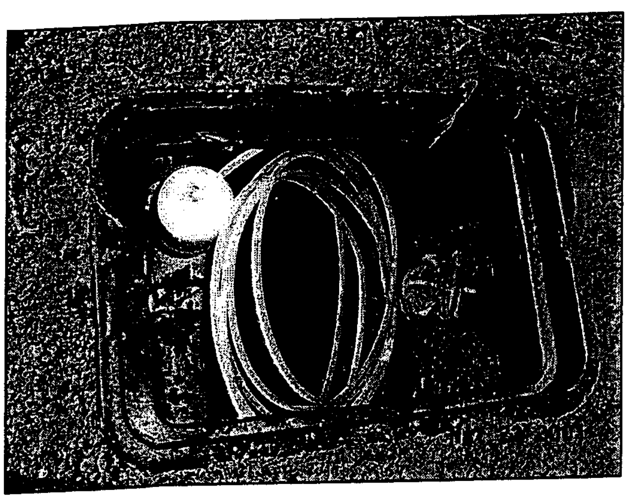


Figure 13: Example *iSOC*™ Wellhead Details

Again, these are examples only. The actual *iSOC*™ installation details will be determined by the design remediation consultant. However, the installation should incorporate both equipment protection from vandalism and easy access features for maintenance and/or monitoring.

Installation & Start Up Procedures

Step 1:
Determine the maximum (head) pressure to which the unit will be subjected. Use the following equation:

Head (psi) = max water depth (ft) / 2.306

Please note that the maximum water depth is **not** the depth of the well itself, but is the **depth of water** in the well.

Step 2:
Install the necessary oxygen supply and control equipment as described above.

Other than protecting the equipment from severe weather and vandalism, the most appropriate installation is flexible and is usually designed to fit the specific site.

Figure 14 illustrates an *iSOC™* installation being completed on an active gasoline service station in Brazil. Note that both the oxygen cylinder and the oxygen control lines and valves are installed in lockable cabinets existing at the station.

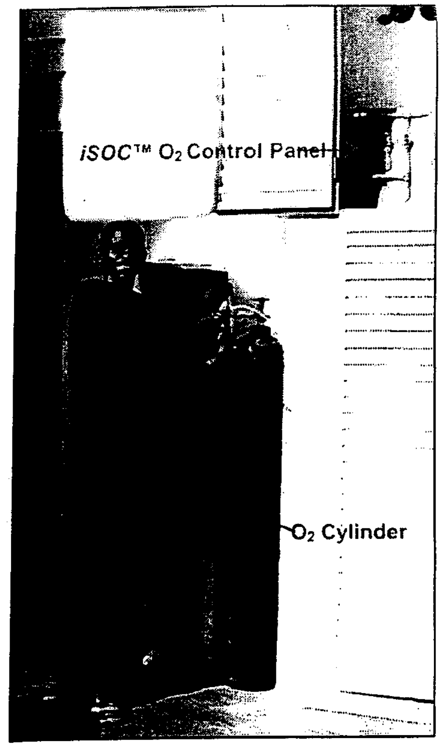


Figure 14: Example *iSOC* O_2 Equipment Installation

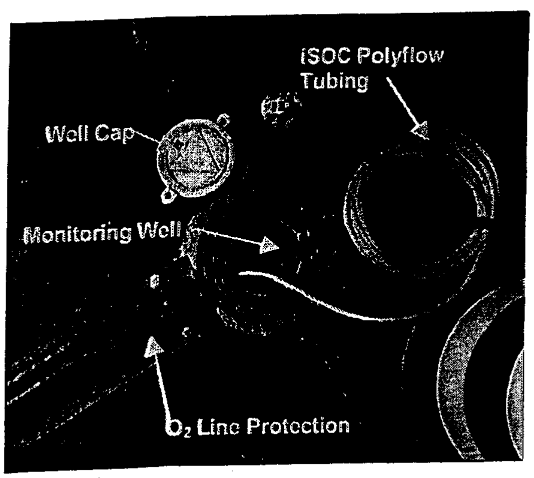


Figure 15: Example *iSOC™* Wellhead Details

Figure 15 illustrates a 2 inch diameter monitoring well, on the traffic area of the same Brazilian service station, ready for *iSOC™* installation.

Note the oxygen supply Polyflow tubing entering the monitoring well from the line protection channel. While this approach uses surface mounted O_2 line protection, Figures 12 and 13 illustrate below ground O_2 line installation in headers.

Both approaches result in *iSOC™* remediation of groundwater beneath an active traffic area.

Step 3:
Connect the Polyflow tubing to the *iSOC*. Be sure that the ¼ inch tubing (plastic nylon or polyethylene) is firmly pushed into the 'push-loc' fitting on the top of the *iSOC*™ (See Figure 16).

If desired, fasten a lifting wire to the lifting eye on top of the unit.

Lower the *iSOC*™ unit to the bottom of the well (See Figs. 12 & 17). Note the lifting line attachment for safe and easy insertion and removal.

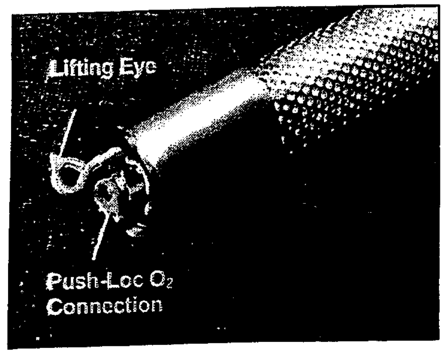


Figure 16: *iSOC*™ O_2 Connection

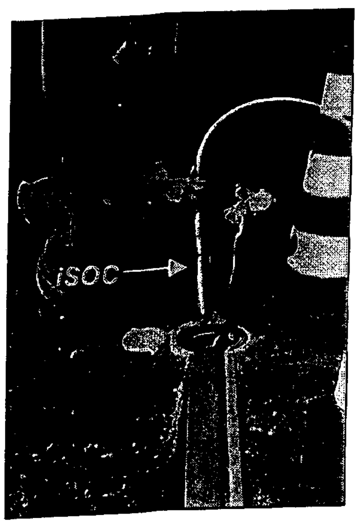


Figure 17: *iSOC*™ Well Insertion

Step 4:
With the bypass valve open, open the oxygen cylinder and adjust the regulator to **6-8 psi above the calculated maximum head** (See Step 1).

Within a few minutes, the system should be purged of air and filled only with oxygen.

Now, reduce the regulator pressure to **1 to 2 psi above the maximum head pressure** and close the bypass valve.

Step 5:
Open the valve on the rotameter. Adjust the valve until the flow indicator 'ball' reads between 60-80 on the scale. This is equivalent to about 7 cc/min. It is not necessary that the 60 to 80 setting be maintained, but it is necessary to maintain the rotameter indicator ball 'on scale' or mid-range.

Step 6:
Test fittings for leaks using leak detector solution.

Step 7:
Although the *iSOC*™ unit is now functioning, it is imperative that the operation of the unit be monitored several times over the first few days to ensure proper operation. At the very low oxygen pressure and flow required by *iSOC*™, a series of adjustments over a few days following start up is often needed to be sure that the regulator pressure has not dropped below the head pressure and that the rotameter reading is still on scale.

Relative to the volume of tubing in the system, the actual amount of gas flow is quite low. Systems such as these respond extremely slowly to small, downward adjustments of flow valves. It is easy to inadvertently turn the rotameter valve off and still have the rotameter ball register a flow for a period of time. This is why iTi recommends that the flow be initially set to 'mid-range'. It allows time for the system to adjust to the valve setting.

Changes in groundwater elevation in the well will affect this setup, requiring regular inspections and adjustments. If the oxygen feed rate has dropped to zero, and the DO reading in the well is below that expected, the *iSOC*™ unit will have to be pulled from the well and drained (See Troubleshooting Section).

In order to prevent a cessation of oxygen flow due to flooding, **iTi recommends that a minimum gas flow of 1-2 cc/min be maintained at all times**. This represents only 2-4 grams of oxygen per day. It should be noted that this extremely small amount of 'excess oxygen' will be released in the form of single large bubbles. Large bubbles exhibit extremely poor mass transfer characteristics. As a result, they will contribute virtually nothing to raising dissolved oxygen levels in the well. **These periodic large bubbles do however promote higher diffusion rates within the well itself and lead to more uniform dissolved oxygen levels throughout the depth of the well.**

It must also be noted that too much 'excess oxygen' flow will not only result in unnecessary wastage, but also can negatively impact the performance of the *iSOC*™ by stripping out the otherwise supersaturated oxygen levels near the top of the well. This is why iTi recommends that the oxygen flow rate always be maintained 'on scale'.

Multiple *iSOC*™ units can be operated from a single source of pressurized oxygen. However, each unit must be installed with its own separate rotameter and bypass valve. In the case of multiple units, the 'maximum water depth' of Step 1 refers to the well with the largest expected head pressure.

Since most commercially available DO (dissolved oxygen) meters are not capable of reading DO concentrations above say 10 to 15 ppm, a special high-range DO meter and probe is required to accurately monitor the DO concentrations created by *iSOC*™ in the application and downstream wells. One such meter is the Oxyguard Alpha High Range Oxygen Meter (See Fig. 19) from Point Four Systems Inc. of Port Moody, British Columbia, Canada (Tel: 604-936-9936; Fax: 604-936-9937; e-mail: sales@pointfour.com; Web: www.pointfour.com. Point Four has representation in many parts of the world.

Troubleshooting

The unit will continue to operate as long as it is not deprived of oxygen. If it is, a vacuum in the *iSOC*™ unit can occur. This can result in water being drawn into the microporous structure, effectively eliminating the large surface area, and reducing or stopping mass transfer. The two major causes are the regulator and the rotameter. As stated above, at very low pressures and very low flows, a series of adjustments over a few days following start up is often needed just to be sure that the regulator pressure has not dropped to below the head pressure, and that the rotameter is still reading on scale. Sometimes it is necessary to 'tap' the rotameter to make sure that the ball is not stuck in the tube. It is not necessary that the rotameter be maintained at 60-80, only that it remain on scale at all times.

Should the *iSOC*™ unit be deprived of oxygen, pull it up to the surface to drain any water from the infusion structure. By removing the drain plug (See Figure 18), drain all water from the device. **With the plug still removed, and the bypass valve open**, set the regulator at 10-15 psi and blow out any water still remaining in the unit. This will take several minutes. Reinstall the drain plug. The unit is now ready for start up.

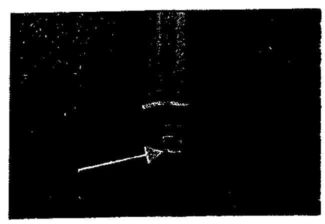


Figure 18: ***iSOC*™ Drain Plug**

It is highly recommended that oxygen flow to the unit be confirmed on a weekly or biweekly schedule and that dissolved oxygen readings in the well be taken at this time as well (See Fig. 19).

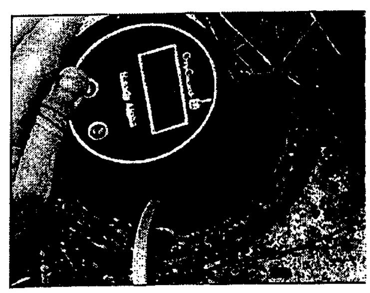


Figure 19: Measuring *iSOC*™ DO

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APPENDIX B

ISOC™ TECHNOLOGY INFORMATION

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Department of Environmental Protection

Jeb Bush
Governor

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Tallahassee, Florida 32399-2400

David B. Struhs
Secretary

September 25, 2001

Mr. Walter S. Mulica
Global Technologies, Inc.
4808 Westridge Drive
Fort Collins, Colorado 80526

Re: **in situ Submerged Oxygen Curtain (iSOC)**

Dear Mr. Mulica:

The Bureau of Petroleum Storage Systems hereby accepts the in situ Submerged Oxygen Curtain (iSOC) as an innovative device that produces dissolved oxygen for in situ biodegradation of petroleum and other aerobically degradable contaminants in groundwater. As indicated by the information you submitted, this "in-the-well" device produces dissolved oxygen concentrations in groundwater in the 50 to 70 parts per million (ppm) range, and greater, without creating bubbles, and is manufactured by inVentures Technology Incorporated, Oakville, Ontario, Canada. It can be used in several ways at contaminated sites, either to create an oxygen barrier curtain, or to treat a source area, or as an enhancement to natural attenuation. Additional information is provided as enclosure 1.

The bureau recognizes the iSOC as a viable product for the bioremediation of petroleum contaminated sites in Florida. There are no objections to its use provided a Remedial Action Plan for the cleanup of petroleum contamination, pursuant to Chapter 62-770, F.A.C., is approved by the Department.

While the Department of Environmental Protection does not provide endorsement of specific or brand name remediation products or processes, it does recognize the need to determine their acceptability from an environmental standpoint with respect to applicable rules and regulations, and the interests of public health, safety, and welfare. Vendors must then market the products and processes on their own merits regarding performance, cost, and safety in comparison to competing alternatives in the marketplace. In no way, however, shall this regulatory acceptance letter be construed as certification of product performance.

Those who prepare Remedial Action Plans are advised to include a copy of this letter in the appendix of plans they submit, and call attention to it in the text of their document. In this way, technical reviewers throughout the state will be informed that you have contacted the Department of Environmental Protection to inquire about the environmental acceptability of this product.

The Department reserves the right to revoke its acceptance of any product or process it has accepted if its nature, performance, or any other aspect has been falsely represented. Additionally, Department acceptance of a product or process does not imply it has been deemed applicable for all cleanup situations, or that it is preferred over other treatment or cleanup techniques in any particular case. A site specific evaluation of applicability and cost-effectiveness must be considered for any product or process, whether conventional or innovative, and adequate site-specific design details must be provided in a Remedial Action Plan. You may contact me at 850/487-3299 if there are any questions.

Sincerely,

Rick Ruscito, P.E.
Bureau of Petroleum Storage Systems

c: John Archibald
inVentures Technology, Inc.
2177 Oakmead Boulevard
Oakville, Ontario L6H 5N4, Canada

T. Conrardy - FDEP/Tallahassee

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ENCLOSURE 1

ADDITIONAL INFORMATION ABOUT iSOC

1. Equipment: Very little equipment is associated with the iSOC. The device itself is made of stainless steel and is 1-3/4 inches in diameter and 15 inches long. It is designed to fit into wells as small as 2 inches in diameter. The only other items needed for its installation are an oxygen cylinder, pressure regulator, valves, rotameter, ¼-inch oxygen tubing, and a suspension line that connects to a lifting eye on the iSOC.

2. Nature of the device: The iSOC contains hydrophobic microporous hollow fibers that provide approximately 7,000 square meters of interface area per cubic meter of fiber for mass transfer of oxygen into the surrounding groundwater. It is an efficient method for the dissolution of oxygen into the groundwater because it does not create bubbles. In comparison, conventional bubble-type systems waste most of the oxygen that is injected, because the bubbles rise to the top of the groundwater table and escape before they have a chance to dissolve.

   The iSOC is capable of producing dissolved oxygen concentrations in groundwater in the range of 50 to 70 parts per million, or greater depending on the atmospheric pressure and the depth at which the device is located below the water table. In comparison, conventional air bubble systems only achieve 6 to 8 ppm of dissolved oxygen in groundwater at ambient temperatures.

   The underlying underlying scientific principle for the iSOC is the equilibrium that exists between the dissolved concentration of a gas in a liquid and the partial pressure of that gas above the liquid. The proportionality constant that relates the partial pressure to the concentration in the dissolved phase is the Henry's Constant, for which additional information is readily available in textbooks.

3. Safety: For iSOC, like any other equipment item used for the remediation of petroleum contaminated sites, the Department expects appropriate safety practices for the handling and use of oxygen cylinders to be observed.

4. Utilization of wells: If a remediation site happens to have an abundance of monitoring wells, then the Department has no objection to the use of some wells for iSOC purposes. However, no "designated" monitoring well, dedicated to the tracking of remediation progress (by sampling) shall be used as an iSOC well. This will avoid premature conclusions that the entire site meets cleanup goals. By making sure that designated tracking wells are not used for the introduction of oxygen, there will be more assurance that dissolved oxygen has permeated the entire site and that it did not remain localized to the area immediately surrounding each iSOC well.

5. Design considerations: As is the case with most in situ remediation strategies, the spacing of injection wells will be depend on site-specific conditions. An example of a barrier curtain contained in one of the iSOC brochures shows three wells, in a line, spaced 16 feet on center, which is equivalent to a radius of influence of 8 feet. For situations where site-specific pilot test information about a radius of influence is not available, the Bureau of Petroleum Storage Systems believes that a 16-foot spacing

would be a reasonable spacing for most Florida sites. The extent to which the dissolved oxygen extends downgradient from each iSOC well will depend on the velocity of the groundwater and the oxygen demand.

6. Oxygen usage: Because the iSOC system does not create bubbles that waste oxygen, it can operate at oxygen flow rates of less than 10 cc/min. One case study presented by the vendor for a 3-well system used three 20-pound oxygen cylinders or approximately 64 pounds of oxygen in a 5-month period. A second case study for a 2-well system use two 20-pound cylinders or approximately 32 pounds of oxygen in a 3-month period.

7. Dissolved oxygen meters: The use of a high-range dissolved oxygen meter, capable of measuring concentrations greater than 15 ppm is recommended. One such meter is the Oxyguard Alpha High Range Oxygen Meter, from Point Four Systems Incorporated, Port Moody, British Columbia, Canada, telephone 604-936-9937.

8. BTEX pilot site results: For one pilot site, during a 6-month period, the average BTEX reduction using iSOC was 60%, with results at individual measuring points ranging from 33% to 96%. For another pilot site, during a 6-month period, the average BTEX reduction using iSOC was 44%, with results at individual measuring points ranging from 0% to 100%.

inVentures
Technologies
incorporated

Creating Value
Through inNovation

Fredericton • Oakville • Ottawa

Introduction to *Gas inFusion* Technology

'elegance in simplicity'

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Gas inFusion Intro: v.iTi.gi.intro.pt.01.01

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Introduction To *Gas inFusion*

Background

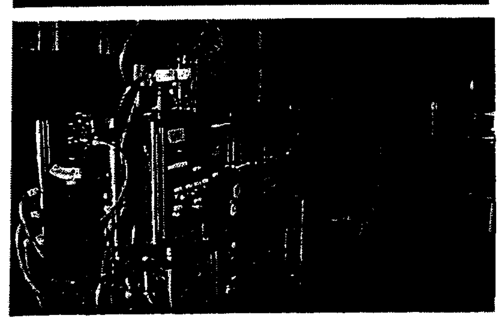
inVentures Technologies incorporated (iTi) has two platform world-class technologies that are based on a membrane-like polymer matrix barrier of microporous hollow fibre. The first technology, referred to as the *Organic Sieve* technology, effectively removes clean, dry organics from an aqueous stream—in-line, under pressure, instantaneously. The second, the *Gas inFusion* technology, infuses ultra-high levels of nascent dissolved gas into liquids. Both technologies have multiple market applications. *Gas inFusion* is patented worldwide, while *Organic Sieve* is patent pending. Both technologies are small, efficient, predictable, easy to use, and elegantly simple.

iTi Vision

The vision of iTi is focused solely on creating value, or enhancing the value of a product or process. Increased value that significantly exceeds the cost of enhancement tends to be an easy sell. The *Gas inFusion* and *Organic Sieve* technologies are platform, best in category and have several very significant market applications. Our clients have emphasized the importance of selling the 'elegant simplicity' of a technology having so many different applications while the technological concept remains the same.

iTi Strategy

inVentures associates itself with institutes and companies that are sound and that will help iTi develop its technology to its fullest potential. iTi recognizes the expertise required to enter these many markets and therefore has chosen not to go to market by itself. iTi always goes to market with industry partners who have a strong/dominant influence in a particular sector. We look to help a strong market player effect significant market growth through our technology. We either license or sell the technology or form some sort of strategic alliance with partners who are already successfully in the market and have a need for our technology. At all times, we have a research institute as a technical partner who helps with research. We have close ties with National Research Council Canada and continue ongoing research programs with them.



Oxygenation of Water 101

Dissolving a gas into a liquid is a 'mass transfer' operation. Mass transfer requires two things to occur:

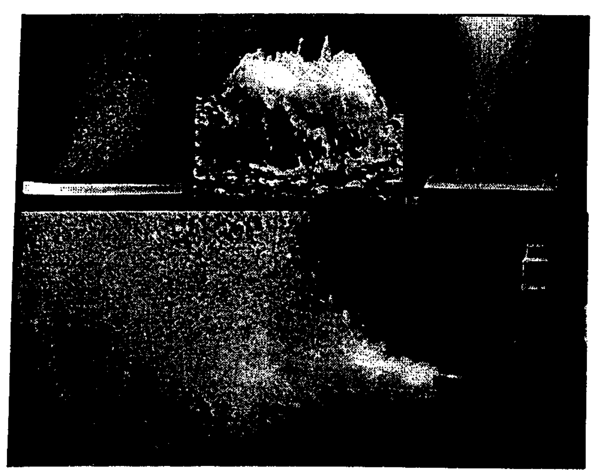
1. First, there must be a 'driving force'. The driving force in a gas/liquid system is the difference between the amount of gas currently in the liquid, and the maximum amount of gas that that liquid can hold, or take into solution, also known as the solubility. The solubility of a gas in a liquid is governed by Henry's Law and is unique to each gas/liquid system.

2. Second, there must be a means or pathway for the gas molecules to contact the liquid stream. This is also known as 'interfacial surface area'.

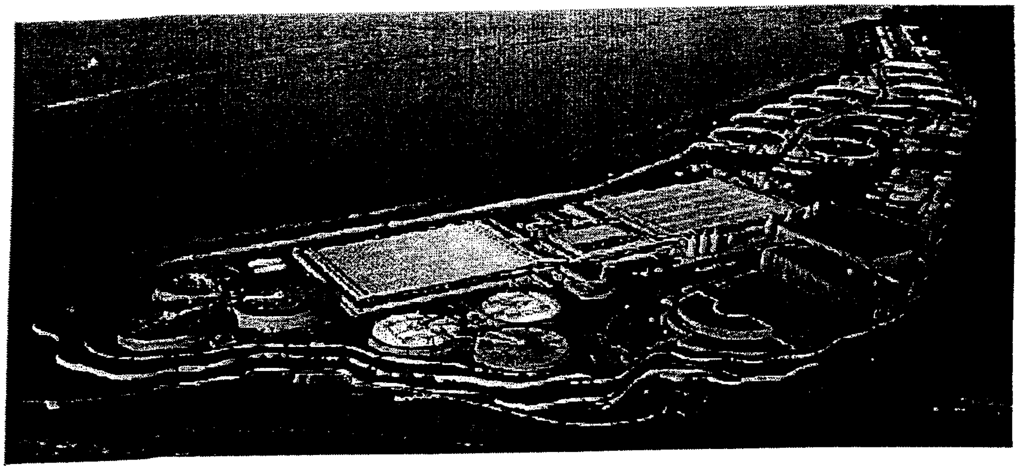
> ***Henry's Law*** *states: The weight of any gas that will dissolve in a given volume of liquid, at constant temperature, is directly proportional to the pressure that the gas exerts above the liquid.*
>
> *In equation form:* $C_{equil} = \alpha \, p_{gas}$
>
> *where:*
>
> C_{equil} *is the concentration of gas dissolved in the liquid at equilibrium;*
> p_{gas} *is the partial pressure of the gas above the liquid; and*
> α *is the Henry's Law constant for the gas at the given temperature.*

Conventional methods of oxygenation of water, as illustrated below, are energy intensive processes. This is due to the fact that oxygen is only sparingly soluble in water. The solubility of atmospheric oxygen in water ranges from about 15 ppm (mg/l) at 0°C to about 7 ppm at 35°C under 1 atmosphere of pressure. Most of the critical conditions related to dissolved oxygen deficiency in biological operations, including bioremediation, occur during the summer months when temperatures are higher and solubility of oxygen is at a minimum. For this reason, it is customary to think of dissolved oxygen levels of about 6 to 8 ppm being the maximum available under critical conditions.

Because of this low solubility, there is very little 'driving force'. In order to accomplish any mass transfer on a reasonable time scale, energy is expended to create interfacial surface area. Fine bubble diffusers, or chemical oxygen production compounds, release oxygen in the form of bubbles, usually in the range of 1 to 2 mm in diameter. These small bubbles create the interfacial surface area required for mass transfer.



Despite their small size, the vast majority of the oxygen (90 to 95%) created by these methods escapes from the water surface into the atmosphere. This escaping oxygen represents a high proportion of wasted energy and wasted money.



For example, the supply of oxygen to suspended biomass in wastewater treatment represents the largest single energy consumer in an activated sludge treatment facility. Recent studies indicate that the aeration system accounts for 50% to 90% of the total power demand. According to industry experts, only about 1% of all oxygen discharged from a fine bubble diffuser is absorbed per foot of tank depth. In a 10-foot deep tank, 90% of the applied oxygen escapes to the atmosphere. Along with the escaped oxygen and air are the noxious odors and VOC's that often require scrubbing at further energy cost.

In any biological treatment process, the limited solubility of oxygen is of great importance because it governs the rate at which oxygen will be absorbed by the medium and therefore, the cost of oxygenation.

Before we discuss how *Gas inFusion* differs from these conventional means of oxygenation, we need to address the concept of how much dissolved gas a liquid can 'hold'. Earlier we described 'solubility' as the maximum amount of gas a liquid can take into solution. This level of dissolved gas 'saturation' is also used extensively and is defined conventionally.

Saturation is defined as:

I. The condition of a liquid when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.

Supersaturation is conventionally defined as:

I. An unstable condition of a vapor in which its density is greater than that normally in equilibrium under the given conditions; or

II. An unstable condition of a solution in which it contains a solute at a concentration exceeding saturation.

Obviously, 'supersaturation' is an unstable condition and not in equilibrium. Now, let's look at why *Gas inFusion™* redefines the concept of 'supersaturation' or more accurately, '***ultra****saturation*'.

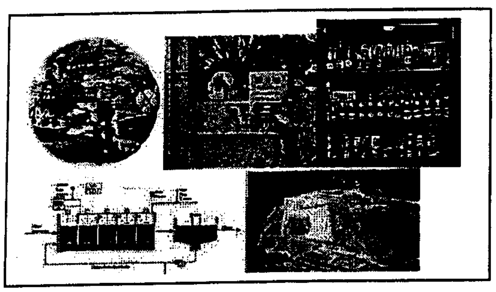
Technological Breakthrough

Gas inFusion technology is a unique method of infusing gas into liquids with demonstrated ability to:

- Effect rapid, no bubble, gas transfer (*inFusion*);
- Create ultra-saturation dissolved gas conditions, e.g., dissolved oxygen concentrations of hundreds of PPM;
- Allow long term retention of extremely high, nascent dissolved gas concentrations;
- Virtually eliminate dissolved gas losses into the atmosphere;
- Achieve gas transfer efficiencies with respect to power used, of 7 to 9 times that of the best conventional methods;
- Produce less dense liquids;
- Enhance performance and increase capacity of existing process infrastructures;
- Be flexible and comparatively small to be fitted into, or parallel to, conventional process technologies; and
- Be easily operated and maintained.

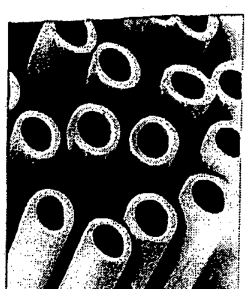
Gas inFusion technology is a global platform technology with numerous potential market uses, both stand alone and bundled with other technologies. iTi is currently focused on several market applications, including:

1. Aquaculture;
2. Live Fish/Seafood Transport;
3. Groundwater remediation;
4. Water/wastewater treatment;
5. Enhanced mineral leaching;
6. Hydroponics;
7. Food and beverage; and
8. Domestic products.

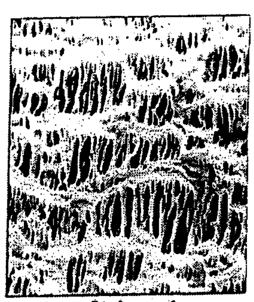


Elegant Simplicity

The infusion of ultra-high levels of nascent dissolved gas is all about mass transfer. Although iTi is definitely not expert in all of the potential market applications for *Gas inFusion*, iTi does have world class expertise in mass transfer.



Cross Section 200 µm



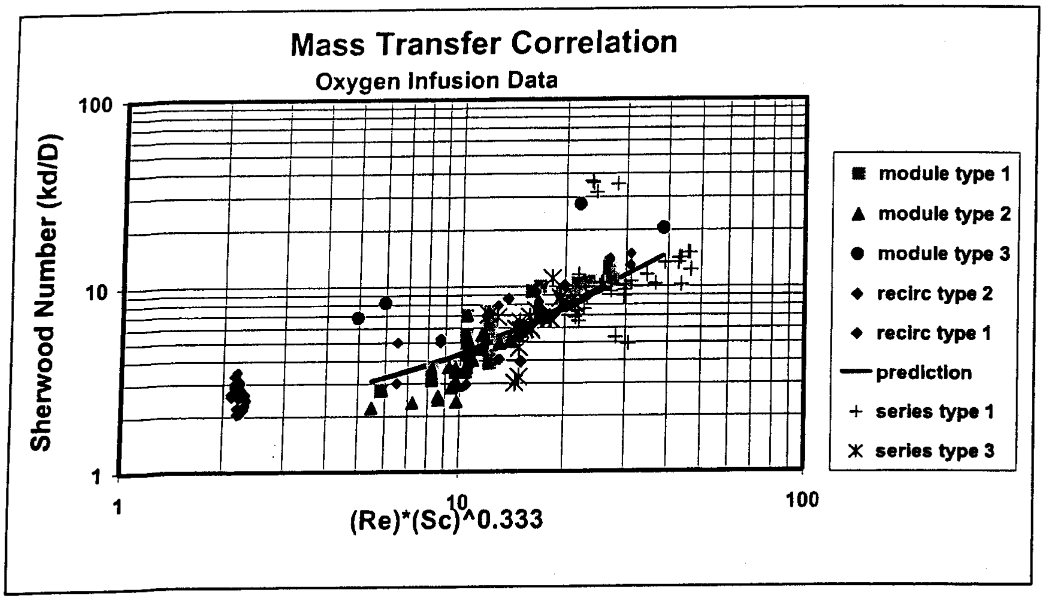
Inner Surface 1 µm

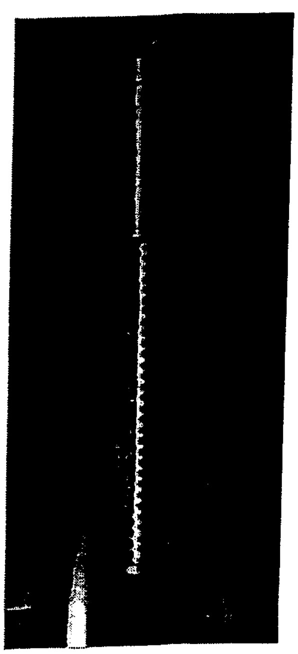
iTi's various *Gas inFusion* devices incorporate an inert polymer matrix barrier made of microporous hollow fibre (MHF). As illustrated, MHF is a type of fibre, about the outside diameter of fishing line, made of various materials, and essentially filled with holes. The size of the hole is controlled in the manufacturing process to produce different fibres with effective pathway diameters of typically 0.1 to 0.5 µm.

MHF produces a stable interface for mass transfer with more surface area, and holes, in the same space than any other material—in excess of 7000 m^2 per m^3—and is hydrophobic. The type and characteristics of the fibre, the size of micropore, and the proprietary designs and techniques developed by iTi determine its effective use in various applications.

Magic Effect—But Science Based

The Mass Transfer Correlation figure below shows that the *Gas inFusion* process is not black magic but is indeed based on solid science and engineering. Not only is the mass transfer predictable for any gas transfer device configuration and design, but custom systems design can also be employed to meet the requirements of any application. The iTi mass transfer predictive model has been proven out many times.



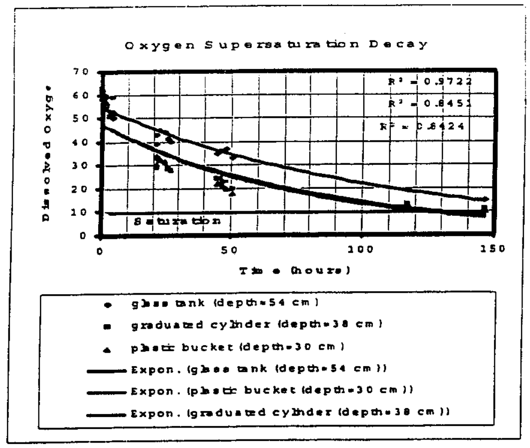


A gas-saturated liquid is produced under pressure within *Gas inFusion* devices, such as the one shown in a column to the left. These *inFusion* devices provide an extremely large interfacial area for gas transfer into a liquid. The transfer is performed such that there are no bubbles. The clear, open top column to the left contains roughly **70 PPM** of dissolved oxygen attached to a standard oxygen cylinder. While the device is actively infusing oxygen into the water, there are **no bubbles**.

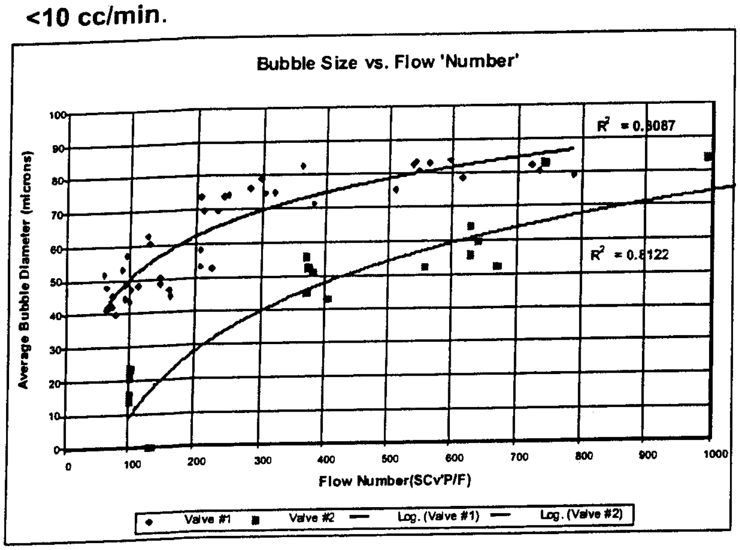
Both the liquid and the gas are under pressure. Henry's Law governs the limit that the liquid concentration can ultimately reach. When the liquid pressure is relieved for use, in an atmospheric tank or basin for example, the liquid is now supersaturated with gas. To prevent atmospheric loss, it is important that the liquid retain the gas as long as possible. When the liquid is introduced into a vessel in a 'bubbleless' fashion, the ultra-saturation condition remains in solution for many days, waiting to be used by process demand, such as biomass in wastewater or groundwater treatment systems.

Supersaturation Decay Test: 3" X 10' column

Time (hours)	DO Reading at Column Depth					
	9'	7'	6'	5'	3'	1'
0	52	53	53	53	52	50
50	42	43	43	43	39	34
100	40	41	41	40	36	32



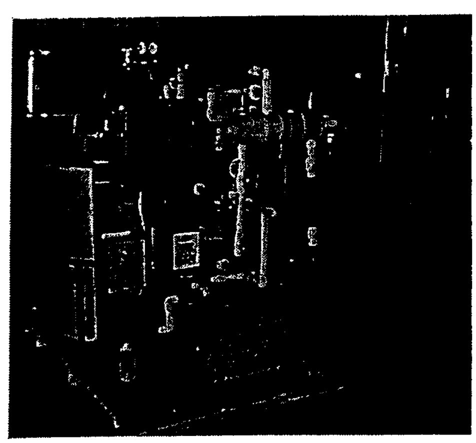
The supersaturation half-life correlates well with the depth of the vessel, as illustrated in the figure to the right. It correlates even better when other dimensional parameters of the vessel are taken into account. Half-lives in excess of a week are obtainable in 10 ft. deep open-top vessels, as shown above, **with oxygen feeds of <10 cc/min**.



As mentioned earlier, the ultra-high dissolved gas content liquid is produced without bubbles. The key to utilizing this gas most efficiently is the understanding of bubble size and growth once the pressure is relieved. As can be seen from the graph to the left, done correctly, extremely fine bubbles of up to 2 orders of magnitude smaller than achievable using the best diffusers on the market can be achieved, if desired.

Flexibility

The unique nature of the *Gas inFusion* technology allows it to be easily fit into an existing process to enhance performance and to increase capacity, or to design a 'grass roots' system around this 'better mouse trap'. Once iTi is aware of the specific needs of a market end use, a prototype gas transfer device can be fabricated to deliver the required results. The usual approach is to run an on-line pilot to test the performance enhancement and to determine the design requirements for a system solution. A typical *Gas inFusion* pilot skid being used for sulfide ore processing is shown on the right—always compact, always flexible.

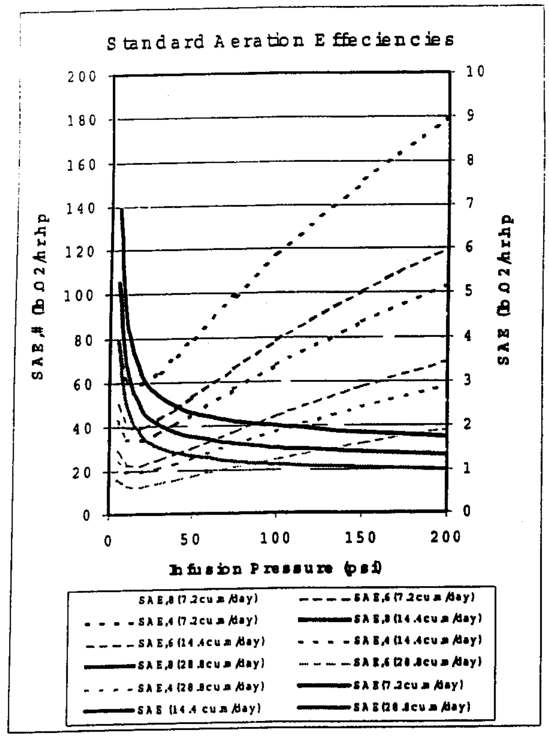


Unconventional Efficiency Saves

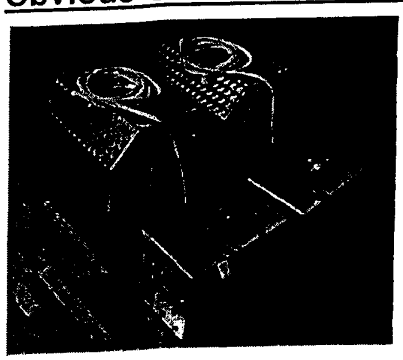
The bottom line is efficiency. In wastewater treatment, for example, enormous amounts of energy are needed to dissolve oxygen into the water. The standard unit of measure is the SAE, or Standard Aeration Efficiency, given in pounds O_2 per hour per horsepower. Conventional technologies achieve a SAE of about 2.0. At the same time, the oxygen concentration in the basin only reaches about 2 PPM. Higher dissolved oxygen concentrations will lower the SAE.

With iTi's *Gas inFusion* technology, and iTi's unique gas transfer devices and *A/Linear* valves, aeration efficiencies illustrated to the right become possible.

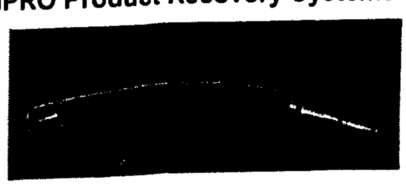
iTi is currently conducting an intensive R&D program in greenhouse gas reduction for wastewater treatment with Canadian federal government support.



Obvious Connection to Groundwater Remediation



iPRO Product Recovery Systems



iPRO Flexible Pump Unit

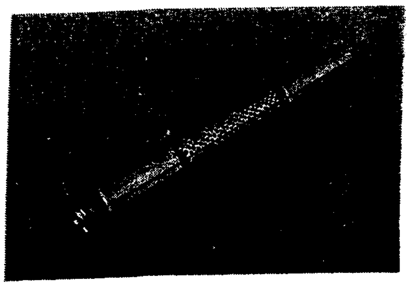
iTi naturally pursued groundwater remediation as an application for the *Gas inFusion* technology as it was already active in designing and manufacturing product recovery equipment. The two *iPRO* product recovery systems illustrated to the left, using iTi's proprietary *Organic Sieve* technology, clearly show the same efficient size approach as with the gas transfer technology. The same performance has also been demonstrated on many sites.

iPRO can be carried as baggage on a plane, or in the trunk of a car, and set up in full operation in a few minutes. *iPRO*, intrinsically safe, and pneumatic driven, recovers clean, dry hydrocarbon product only—absolutely no water—resulting in a product that can be re-used or re-sold. The pneumatic pump automatically seeks out the product/water interface continuously over any depth up to 250 feet. The product is removed down to a layer of 4 microns. Any accumulations of product are automatically recovered with little or no maintenance.

The combination of *iPRO* , *iSOC*, and *A/Linear* Valves (all described below) creates a one-two punch for both liquid phase LNAPL's and dissolved organics in the groundwater. This simple, inexpensive approach achieves immediate site remediation and an effective control of ongoing environmental liability exposure for contaminated property.

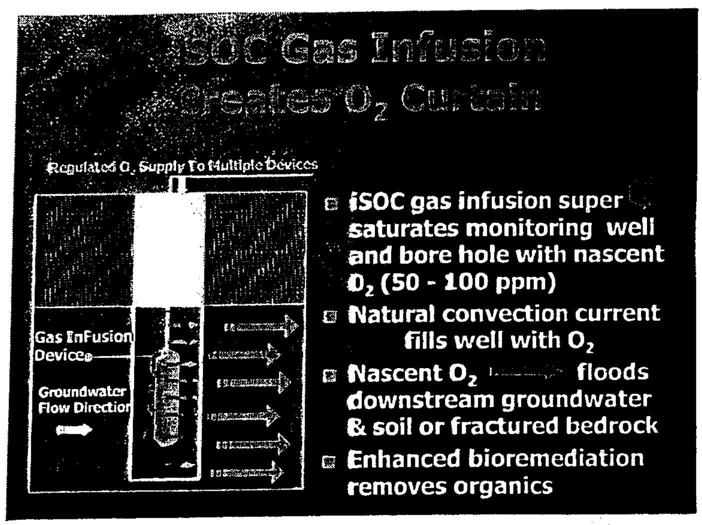
iSOC—Passive 'No Power' Groundwater Oxygenation

The benefits of enhanced biodegradation in cleaning up groundwater contaminated by organic components is well known, well documented, and widely used throughout the world. The addition of air, oxygen and oxidizing chemicals, as well as nutrients, has demonstrated successful results in enhancing natural attenuation.

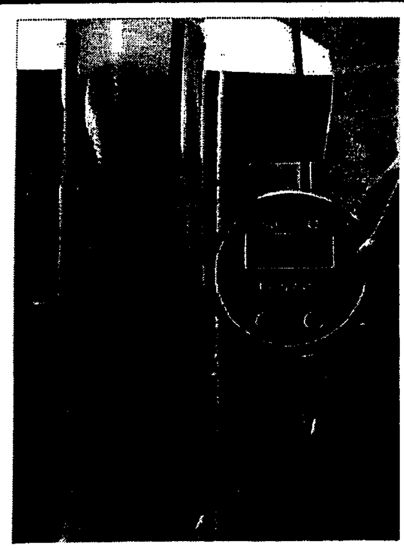


iSOC—in situ Submerged Oxygen Curtain—is a *Gas inFusion* gas transfer device made to operate with no power, and a simple connection to a standard oxygen cylinder. The stainless steel *iSOC* is suspended down 2-inch diameter monitoring wells to create dissolved oxygen (DO) levels in the well of 50 to 300 PPM depending on well and groundwater characteristics, increasing with depth.

This state-of-the-art *Gas inFusion* mass transfer process delivers ultra-high, cost-efficient concentrations of dissolved oxygen directly into contaminated ground water. The greatly enhanced level of oxygenated ground water addresses dissolved-phase petroleum hydrocarbon contamination as well as sorbed material in the saturated, capillary fringe, and smear zones. The *iSOC* can create an enhanced O_2 curtain or barrier to prevent contamination migration thus making *iSOC Gas inFusion* an ideal enhancement to obtain approval for Monitored Natural Attenuation.

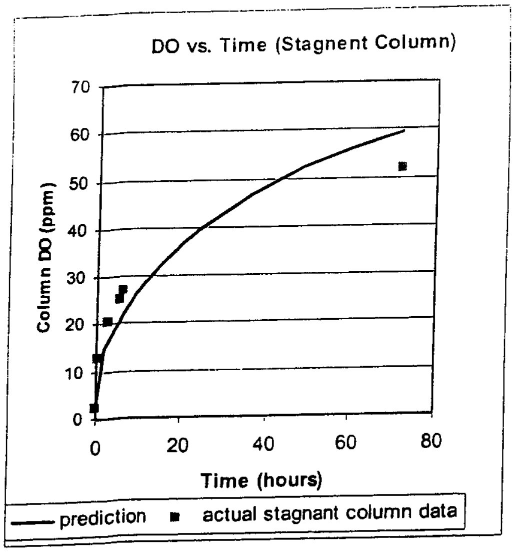


If seeing is believing, check the photograph to the right—the specially adapted high-range DO meter reads 51 PPM in a 10-foot, open top column. The blue line is the oxygen line to the *iSOC* located at the bottom of the column and the DO meter probe is shown in the bubble-free water. That's it, nothing else.



iSOC infuses an order of magnitude more DO than any competitive technology, and is the most cost effective solution to many hydrocarbon contamination problems. In many situations, a standard oxygen cylinder will supply an *iSOC* for about a year. Like everything else that iTi invents, *iSOC* is small, efficient, predictable, elegantly simple, and easy to use.

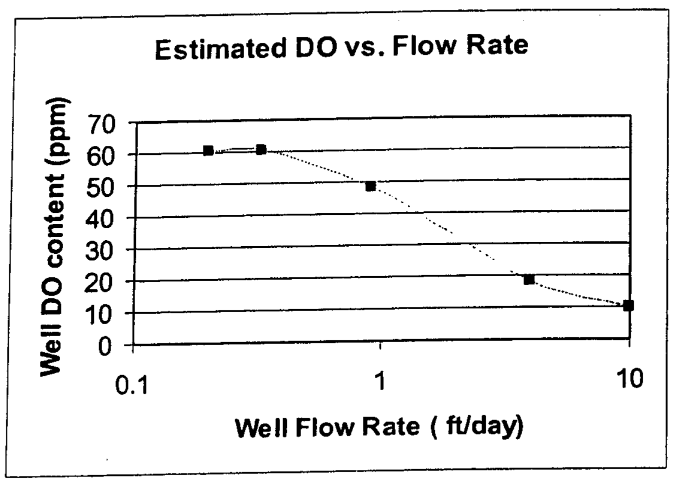
Proof In Data



If proof is in data, the graph illustrated on the left relates to 'passive' infusion of a gas into a column (or vessel) of liquid. No power is required for the mass transfer to occur. As shown, the iTi predictive model is accurately proven out.

In the 'real life' field, the *iSOC* and line are purged with oxygen once installed to overcome the natural boundary layer and to accelerate the creation of a fully oxygenated well.

The graph to the right is specific to the case of downhole groundwater remediation. As the groundwater flow rate increases, more super-saturated water is removed from the well, thus increasing the oxygen demand and lowering the DO level in the well. This is good. It is important to note that the mass transfer is generic to all gases, not just oxygen.



iSOC Passive Do Performance

iSOC will deliver about 43 PPM of dissolved oxygen (DO) per atmosphere of head pressure on the *iSOC* unit. Based on standard atmospheric pressure of 14.7 psi at sea level to about 10 psi at 10,000 feet elevation, an *iSOC* unit positioned at the bottom of a well with a water depth of 35 feet—roughly 2 atmospheres—can be expected to deliver in the order of 86 PPM DO. This is simply based on the atmospheric pressure of 14.7 psi plus the water head pressure of 15.2 psi creating a total pressure of 29.9 psi, or about 2 atmospheres.

Remember Henry's Law, which states: *the weight of any gas that will dissolve in a given volume of liquid, at constant temperature, is directly proportional to the pressure that the gas exerts above the liquid.*

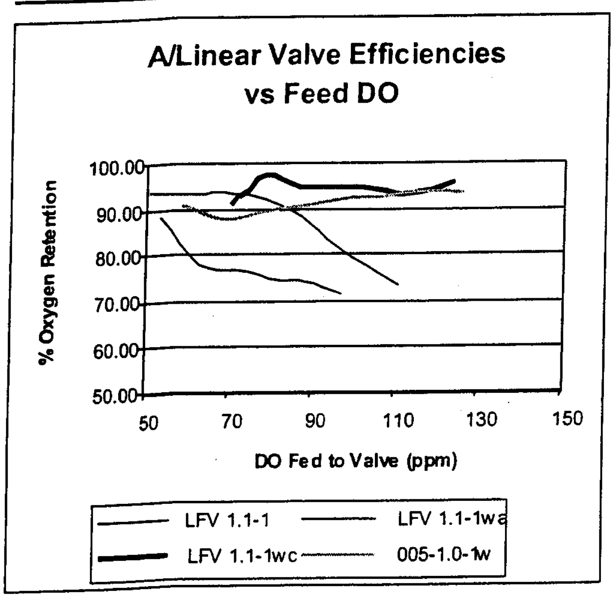
Concept Becomes Fact—*A/Linear*

As stated above, *iSOC* is capable of delivering very high levels of DO passively depending on the depth of water over the *iSOC*. Where higher DO levels are required, higher pressures must be used. This is where iTi employs small *Gas inFusion* skids equipped with larger gas transfer devices and a pump to create the required pressure.

In this 'active' form of *Gas inFusion*, it is essential that a laminar flow valve be used as part of the supersaturated flow discharge to eliminate immediate loss of dissolved gas across a normal valve. Once bubbles are formed in an uncontrolled fashion, the gas levels are quickly stripped to form larger bubbles. Since commercially available laminar flow valves did not allow the ultra-high performance possible with *Gas inFusion*, iTi invented a more efficient laminar flow valve capable of delivering even higher levels of dissolved gas into atmospheric pressure vessels or groundwater regimes.

As a result, and as part of its bubble size research with the National Research Council of Canada, iTi redefined the concept of linear laminar flow valves. iTi's patent pending 'valves' employ the same hollow fibre technology to drop the pressure of a gas saturated stream to produce a supersaturated stream containing controllable bubble sizes and quantities. The flow through the valve is always highly laminar and the pressure drop is absolutely linear, thus its name—***A/Linear***. By altering the valve's fibre characteristics, the valve can be sized for a wide variety of applications, including iTi's current application markets of wastewater treatment, aquaculture and groundwater remediation.

Outstanding A/Linear Efficiency

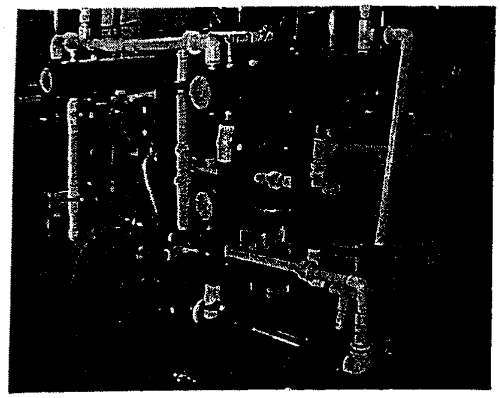


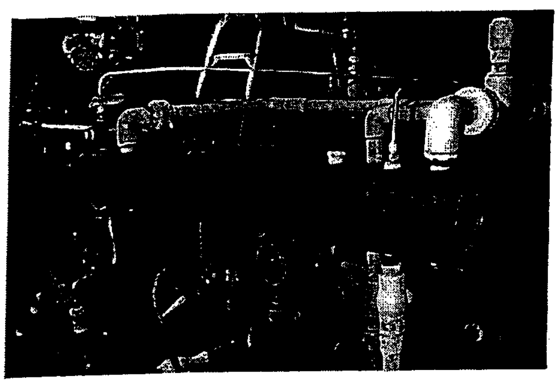
The efficiency of a valve, with respect to *Gas inFusion*, needs to be defined as the ability to retain the gas in a dissolved state. In a dissolved state, the gas will be more readily available to be utilized and less likely to escape to the atmosphere. Also, the ultra-saturated stream will mix with water with a low dissolved gas level with less loss to the atmosphere. This illustrates one of the prime functions of this infusion technology—to mix a small amount of ultra-saturated liquid with liquid deficient in dissolved gas—any gas.

With no moving parts, the *A/Linear* valves not only relieve the liquid pressure linearly versus liquid throughput, but the *A/Linear* valve also makes it possible to retain extremely high amounts of the dissolved gas. Naturally, each *A/Linear* valve design configuration produces its own unique bubble size distribution, and its own gas retention efficiency. The *A/Linear* laminar flow valve forms a basic part of all iTi 'active' *Gas inFusion* equipment solutions.

Ultra-High Groundwater Gas Transfer

Through the use of larger iTi gas transfer devices (shown below), and a small skid (shown at right) equipped with specific equipment for a specific application, dissolved gas concentrations can be attained that previously were considered impossible. A low-flow stream of water containing **hundreds of PPM of dissolved gas** can be injected downhole with the *A/Linear* valve directly into the contaminated groundwater through any well equal or greater than 2-inches in diameter.

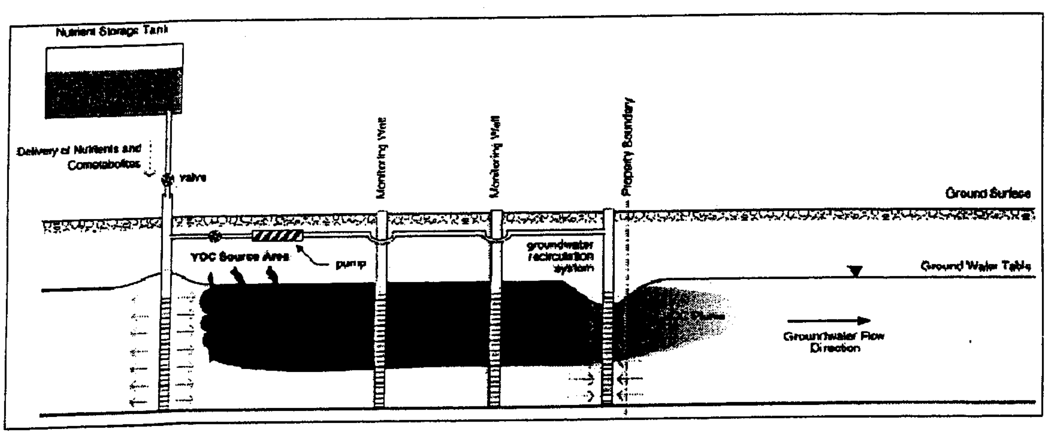




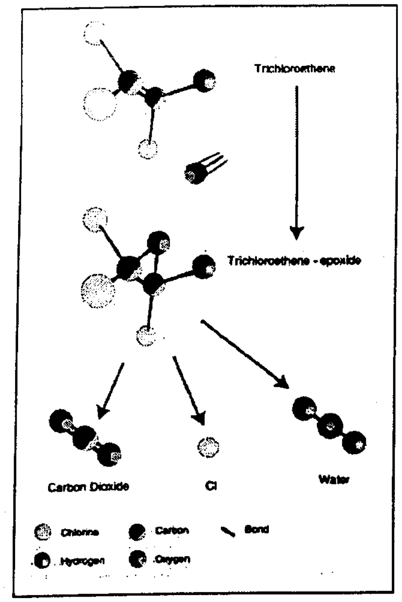
This ultra-saturated water, without bubbles or loss to the atmosphere, then mixes with the in situ groundwater to create a nascent oxygen (or any other gas) supply for extremely effective biodegradation.

The only power involved is provided through pumping the ultra-saturated water stream—something that is normally available on any site.

The *Gas inFusion* equipment, usually a small, flexible skid, can be easily fit into most existing groundwater remediation systems to greatly enhance and accelerate contaminant cleanup, especially when nutrient addition is used, as shown below.



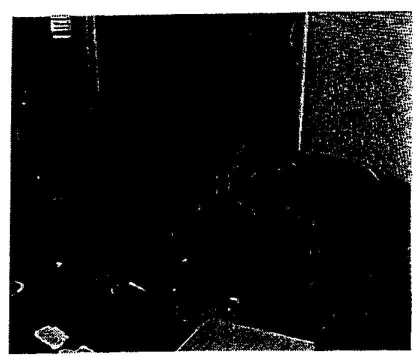
Chlorinated Solvents



Chlorinated organic chemicals such as trichloroethane, trichloroethylene, perchlorethylene, carbon tetrachloride and chloroform have been widely used as solvents in manufacturing, dry cleaning, and metal cleaning in the post-World War II era. Not surprisingly, chlorinated solvents have been identified as the most common industrial contaminants in groundwater in Europe and North America.

Since the first reporting of groundwater contamination from chlorinated solvents in the late 1970's and early 1980's, billions of dollars have been spent annually in North America and Europe in an attempt to restore groundwater systems beneath sites contaminated with chlorinated solvents. This generally has been unsuccessful.

iMOX—Potential DNAPL Edge



iTi's *Gas inFusion* technology applies to **all gases**. Although most of iTi's R&D thus far has been based on oxygen, the same performance can be achieved subject to the solubility of the gas in water. For example, since methane is about 60 per cent as soluble as oxygen, dissolved methane concentrations of 60 per cent of hundreds of PPM can be produced.

With the firm belief that iTi's unique gas transfer abilities will enable more effective remediation of chlorinated solvents, iTi has developed a prototype gas transfer device for DNAPL use.

iMOX—in situ coMetabolic OXidation—a device similar to *iSOC*, is capable of passive infusion of the necessary gas directly into the groundwater. The levels produced downhole are again dependent upon the solubility of the gas in water as compared to oxygen.

Combining an iTi *Gas inFusion* skid with the *A/Linear* valve installed downhole in 2-inch diameter wells creates the capability to introduce ultra-high gas transfer directly into the chlorinated solvent contaminated groundwater. This raises the following questions:

- Is it beneficial to deliver methane or natural gas directly to the DNAPL plume in concentrations of several hundred PPM?
- Is it beneficial to deliver hydrogen directly to the DNAPL plume in concentrations in the range of 20 PPM?
- Is it beneficial to deliver this dissolved gas concentration in a bubbleless, nascent form that does not readily decay and is immediately available to biomass?
- Is it acceptable to achieve this level of gas transfer by ultra-saturating a small volume of water and injecting it into the DNAPL plume?
- And/or, is it more acceptable to deliver somewhat lower dissolved gas concentrations through a passive *iMOX* device directly into the groundwater?

If any of the above questions are yes, we need to talk. The mass transfer expertise of iTi combined with the groundwater remediation expertise of a potential partner can redefine the cleanup industry. Right now, this is an iTi developmental concept.

ZEGi - Zero Energy Gas inFusion

One area that iTi is currently experimenting with is an innovative concept of using atmospheric air to raise the dissolved oxygen content of water—without any compression or air handling of any kind. We have named, and provisionally patented this concept, as ***ZEGi***, or ***Zero Energy Gas inFusion***.

Typically, water and wastewater systems requiring aeration already involve liquid movement as the liquid is pumped or flows from one unit process to another, or as water flows in a stream. *ZEGi* uses this 'energy' of movement to draw air (oxygen) into the liquid through a *ZEGi* gas transfer device. No other energy is used, but the transfer efficiency offered by the enormous interfacial surface area is impressive and exciting. At liquid flows of only 2 or 3 GPM, the dissolved oxygen in preliminary tests has been raised by about 30 PPM instantaneously with a single *ZEGi* device.

iTi is currently conducting intensive R&D work on *ZEGi* as part of a Canadian federal government supported greenhouse gas reduction program in wastewater treatment. The iTi program team includes wastewater treatment experts, one of the largest wastewater treatment plant owners in North America, and an international gas supplier.

The potential market opportunities for *ZEGi* are substantial.

iTi Challenge

iTi is, and always will be, a technology company. The challenge we face ourselves with each day is to 'push the envelope' of the *Gas inFusion* technology—both in its capabilities and its potential market applications.

The challenge we face our strategic partners with is to adopt this technology through a licensing arrangement and to create and redefine value enhancement through the development and application of *Gas inFusion* to these markets. Meeting this challenge can result in a win-win-win combination for the client, our partner, and iTi—creating value added success through innovation.

If you are a potential strategic partner, or you have a market application that may demand an innovative solution based on iTi's *Gas inFusion* or *Organic Sieve* technologies, contact iTi at the addresses listed in the following Contact section.

Gas inFusion ***iPRO*** ***ZEGi*** ***iSOC*** ***A/Linear*** ***iMOX*** ***Organic Sieve***

Creating Value Through inNovation

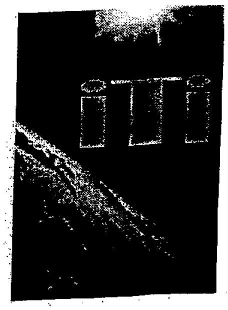
iTi CONTACT

inVENTURES TECHNOLOGIES iNCORPORATED

Oakville, Ontario,
Office - Canada

John Archibald, P.Eng.
Managing Partner
2177 Oakmead Blvd.
Oakville, ON L6H 5N4
Canada

Tel: 905-339-1543
Fax: 905-339-1923
E-mail: jarch@attglobal.net



Creating Value
Through inNovation

Fredericton • Oakville • Ottawa

Sales & Inquiries:

Performance Technologies

Advanced Environmental Solutions

Performance Technologies, Inc. • 337 Hunters Crossing • Tallahassee, FL
USA 32312 • Tel: 850-385-7790 • Fax: 850-894-1067
Email: donrayoffice@home.com

APPENDIX C

FIELD FORMS

Tetra Tech NUS, Inc.

DAILY ACTIVITIES RECORD

PROJECT NAME: OLF BRONSON SITE 1140NW PROJECT NUMBER: N4250

CLIENT: SOUTHNAVFACENGCOM LOCATION:

DATE: ARRIVAL TIME:

Tt NUS PERSONNEL: DEPARTURE TIME:

CONTRACTOR: DRILLER:

Item Description	QUANTITY ESTIMATE	QUANTITY TODAY	PREVIOUS TOTAL QUANTITY	CUMULATIVE QUANTITY TO DATE

LOCATION	FOOTAGE		IDW Drum Labels	

COMMENTS:

APPROVED BY:

Tt NUS REPRESENTATIVE

DRILLER

DATE:

Tetra Tech NUS, Inc.

BORING LOG

Page ___ of ___

PROJECT NAME: OLF BRONSON SITE 1140NW
BORING NUMBER:
PROJECT NUMBER: N4250
DATE:
DRILLING COMPANY:
GEOLOGIST:
DRILLING RIG:
DRILLER:

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION			USCS *	Remarks	PID/FID Reading (ppm)			
					Soil Density/ Consistency or Rock Hardness	Color	Material Classification			Sample	Sampler BZ	Borehole**	Driller BZ**

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Remarks:

Drilling Area Background (ppm):

Converted to Well: Yes ______ No ______ Well I.D. #:

Tetra Tech NUS, Inc.

GROUNDWATER LEVEL MEASUREMENT SHEET

Project Name: OLF BRONSON SITE 1140NW
Project No.: N4250
Location: ____
Personnel: ____
Weather Conditions: ____
Measuring Device: ____
Tidally Influenced: Yes ____ No ____
Remarks: ____

Well or Piezometer Number	Date	Time	Elevation of Reference Point (feet)*	Total Well Depth (feet)*	Water Level Indicator Reading (feet)*	Thickness of Free Product (feet)*	Groundwater Elevation (feet)*	Comments

* All measurements to the nearest 0.01 foot

Tetra Tech NUS, Inc. **GROUNDWATER SAMPLE LOG SHEET**

Project Site Name:	OLF BRONSON SITE 1140NW	Sample ID No.:	
Project No.:	N4250	Sample Location:	
[ ] Domestic Well Data		Sampled By:	
[X] Monitoring Well Data		C.O.C. No.:	
[ ] Other Well Type:		Type of Sample:	
[ ] QA Sample Type:		[X] Low Concentration	
		[ ] High Concentration	

SAMPLING DATA

Date:	Color Visual	pH Standard	S.C. mS/cm	Temp. °C	Turbidity NTU	DO mg/l	Salinity %	Other
Time:								
Method: Low Flow Peristaltic								

PURGE DATA

Date:	Time	pH	S.C.	Temp (°C)	Turbidity	DO	Salinity	ORP
Method: Low Flow Peristaltic								
Monitor Reading (ppm):								
Well Casing Diameter:								
Well Casing Material:								
Total Well Depth (TD):								
Static Water Level (WL):								
One Casing Volume(gal/L):								
Start Purge (hrs):								
End Purge (hrs):								
Total Purge Time (min):								
Total Vol. Purged (gal/L):								

SAMPLE COLLECTION INFORMATION

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES

Circle if Applicable:		Signature(s):
MS/MSD	Duplicate ID No.:	

Tetra Tech NUS, Inc.

FIELD ANALYTICAL LOG SHEET
GEOCHEMICAL PARAMETERS

Project Site Name: OLF BRONSON SITE 1140NW
Sample ID No.: ____
Project No.: N4250
Sample Location: ____
Sampled By: ____
Duplicate: ☐
Field Analyst: ____
Blank: ☐
Field Form Checked as per QA/QC Checklist (initials): ____

SAMPLING DATA:

Date: / Time: / Method:	Color (Visual)	ORP (Eh) (+/- mv)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (Meter, mg/l)	Sal. (%)	pH (SU)

SAMPLE COLLECTION/ANALYSIS INFORMATION:

Dissolved Oxygen:

Equipment: HACH Digital Titrator OX-DT CHEMetrics (Range: _______mg/L) Analysis Time: ________

Range Used:	Range	Sample Vol.	Cartridge	Multiplier
☐	1-5 mg/L	200 ml	0.200 N	0.01
☐	2-10 mg/L	100 ml	0.200 N	0.02

Titration Count	Multiplier	Concentration
________	x 0.01	= mg/L
________	x 0.02	= mg/L

CHEMetrics: ________mg/L

Notes:

Alkalinity:

Analysis Time: ________

Equipment: HACH Digital Titrator AL-DT CHEMetrics (Range: _______mg/L) Filtered: ☐

Range Used:	Range	Sample Vol.	Cartridge	Multiplier	Titration Count	Multiplier	Concentration
☐	10-40 mg/L	100 ml	0.1600 N	0.1	______ & ______	x 0.1	= mg/L
☐	40-160 mg/L	25 ml	0.1600 N	0.4	______ & ______	x 0.4	= mg/L
☐	100-400 mg/L	100 ml	1.600 N	1.0	______ & ______	x 1.0	= mg/L
☐	200-800 mg/L	50 ml	1.600 N	2.0	______ & ______	x 2.0	= mg/L
☐	500-2000 mg/L	20 ml	1.600 N	5.0	______ & ______	x 5.0	= mg/L
☐	1000-4000 mg/L	10 ml	1.600 N	10.0	______ & ______	x 10.0	= mg/L

Parameter:	Hydroxide	Carbonate	Bicarbonate
Relationship:			

CHEMetrics: ________mg/L

Notes:

Standard Additions: ☐ Titrant Molarity:________ Digits Required: 1st.:________ 2nd.:________ 3rd.:________

Carbon Dioxide:

Equipment: HACH Digital Titrator CA-DT CHEMetrics (Range: _______mg/L) Analysis Time: ________

Range Used:	Range	Sample Vol.	Cartridge	Multiplier
☐	10-50 mg/L	200 ml	0.3636 N	0.1
☐	20-100 mg/L	100 ml	0.3636 N	0.2
☐	100-400 mg/L	200 ml	3.636 N	1.0
☐	200-1000 mg/L	100 ml	3.636 N	2.0

Titration Count		Concentration
________	x 0.1	= mg/L
________	x 0.2	= mg/L
________	x 1.0	= mg/L
________	x 2.0	= mg/L

CHEMetrics: ________mg/L

Notes:

Standard Additions: ☐ Titrant Molarity:________ Digits Required: 1st.:________ 2nd.:________ 3rd.:________

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET
NATURAL ATTENUATION PARAMETERS

Project Site Name: OLF BRONSON SITE 1140NW

Project No.: N4250

Sample ID No.: ____________

Sample Location: Site No.

Sampled By: ____________

SAMPLING DATA:

	Color (Visual)	pH (SU)	S.C. (mS/cm)	Temp. (^oC)	Turbidity (NTU)	DO (Meter, mg/l)	Sal. (%)	
Date:								
Time:								
Method: Peristaltic pump								

SAMPLE COLLECTION/ANALYSIS INFORMATION:

Sulfide:

Equipment: HACH DR-700 Colorimeter HACH DR-800 Colorimeter HACH HS-C Test Kit

Wave / Program: 610nm / 61.12.1

TtNUS Serial No.: ____________

Concentration: ____________ mg/L

Ferrous Iron:

Equipment: HACH DR-700 Colorimeter HACH DR-800 Colorimeter HACH IR-18C Test Kit

Wave / Program: 500nm / 50.05.1

TtNUS Serial No.: ____________

Concentration: ____________ mg/L

Manganese:

Equipment: HACH DR-700 Colorimeter HACH DR-800 Colorimeter

Wave / Program: 525nm / 52.13.1

TtNUS Serial No.: ____________

Concentration: ____________ mg/L

Tetra Tech NUS, Inc.

FIELD ANALYTICAL LOG SHEET
GEOCHEMICAL PARAMETERS

Project Site Name: OLF BRONSON SITE 1140NW
Sample ID No.: ______
Project No.: N4250
Sample Location: ______
Sampled By: ______
Duplicate: ☐
Field Analyst: ______
Blank: ☐
Field Form Checked as per QA/QC Checklist (initials): ☐

SAMPLE COLLECTION/ANALYSIS INFORMATION:

Manganese (Mn^{2+}):

Equipment: DR-700 DR-8__ HACH MN-5 Other: ______ Analysis Time: ______
Program/Module: 525nm 41
Concentration: ______ mg/L Filtered: ☐
Digestion: ☐
Standard Solution: ☐ Results: ______ Reagent Blank Correction: ☐
Standard Additions: ☐ Digits Required: 0.1ml: ______ 0.2ml: ______ 0.3ml: ______
Notes: ______

Ferrous Iron (Fe^{2+}):

Equipment: DR-700 DR-8__ IR-18C Color Wheel Other: ______ Analysis Time: ______
Program/Module: 500nm 33
Concentration: ______ mg/L Filtered: ☐
Notes: ______

Hydrogen Sulfide (H_2S):

Equipment: HS-C Other: ______ Analysis Time: ______
Concentration: ______ mg/L Exceeded 5.0 mg/L range on color chart: ☐
Notes: ______

QA/QC Checklist:

All data fields have been completed as necessary: ☐
Correct measurement units are cited in the SAMPLING DATA block: ☐
Mulitplication is correct for each *Multiplier* table: ☐
Final calulated concentration is within the appropriate *Range Used* block: ☐
Alkalinity *Relationship* is determined appropriatly as per manufacturer instructions: ☐
QA/QC sample (e.g., Std. Additions, etc.) frequency is appropriate as per the project planning documents: ☐
Nitrite Interference treatment used for Nitrate test if Nitrite was detected: ☐
Title block is initialized by person who performed the QA/QC Ckecklist: ☐

Tetra Tech NUS, Inc.

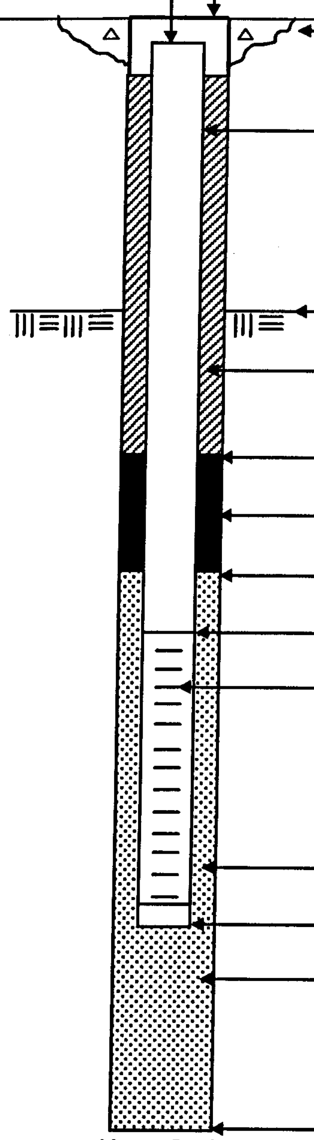
WELL No.: ____________

MONITORING WELL SHEET

PROJECT:	OLF BRONSON	DRILLING Co.:		BORING No.:	
PROJECT No.:	N4250	DRILLER:		DATE COMPLETED:	
SITE:	SITE 1140 NW	DRILLING METHOD:		NORTHING:	
GEOLOGIST:		DEV. METHOD:		EASTING:	

Ground Elevation =

Datum:



Not to Scale

Elevation / Depth of Top of Riser: ____ / ____

Elevation / Height of Top of Surface Casing: ____ / ____

I.D. of Surface Casing: 8"

Type of Surface Casing: Steel

Type of Surface Seal: ____________

I.D. of Riser: ____________

Type of Riser: PVC

Borehole Diameter: ____________

Elevation / Depth Top of Rock: ____ / ____

Type of Backfill: ____________

Elevation / Depth of Seal: ____ / ____

Type of Seal: 30/65 Sand

Elevation / Depth of Top of Filter Pack: ____ / ____

Elevation / Depth of Top of Screen: ____ / ____

Type of Screen: PVC

Slot Size x Length: ____________

I.D. of Screen: ____________

Type of Filter Pack: ____________

Elevation / Depth of Bottom of Screen: ____ / ____

Elevation / Depth of Bottom of Filter Pack: ____ / ____

Type of Backfill Below Well: ____________

Elevation / Total Depth of Borehole: ____ / ____

Tetra Tech NUS, Inc.

MONITORING WELL DEVELOPMENT RECORD

Well: ____________________
Site: _____ SITE 1140NW
Date Installed: ____________________
Date Developed: ____________________
Dev. Method: ____________________
Pump Type: ____________________

Depth to Bottom (ft.): ____________
Static Water Level Before (ft.): ________
Static Water Level After (ft.): ________
Screen Length (ft.): ____________
Specific Capacity: ____________
Casing ID (in.): ____________

Responsible Personnel: ____________________
Drilling Co.: ____________________
Project Name: TREATABILITY STUDY OLF BRONSON
Project Number: N4250

Time	Estimated Sediment Thickness (Ft.)	Cumulative Water Volume (Gal.)	Water Level Readings (Ft. below TOC)	Temperature (Degrees C)	pH	Specific Conductance (Units ____)	Turbidity (NTU)	Remarks (odor, color, etc.)

Tetra Tech NUS, Inc.

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: OLF BRONSON - SITE 1140NW

PROJECT NUMBER: N4250

WELL ID.: ____________________

DATE: ____________________

Time	Water Level	Flow	pH	Cond.	Turb.	DO	Temp.	ORP	Comments
(Hrs.)	(Ft. below TOC)	(mL/Min.)	(S.U.)	(mS/cm)	(NTU)	(mg/L)	(Celsius)	(mV)	

SIGNATURE(S): ____________________

PAGE___OF___

Tetra Tech NUS, Inc.

EQUIPMENT CALIBRATION LOG

PROJECT NAME : TREATABILITY STUDY OLF BRONSON

SITE NAME: SITE 114NW

PROJECT No.: N4250

INSTRUMENT NAME/MODEL:

MANUFACTURER:

SERIAL NUMBER:

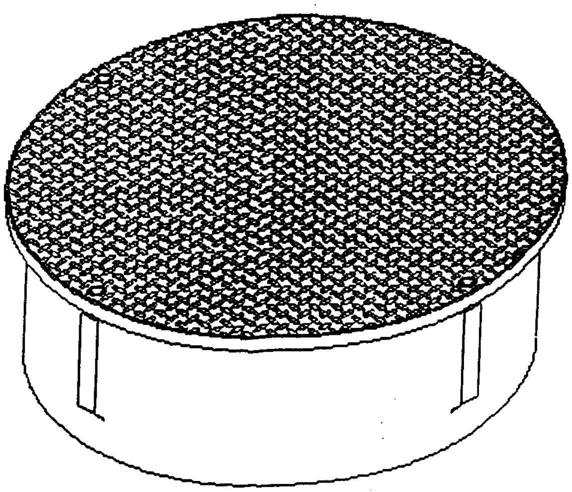
Date of Calibration	Instrument I.D. Number	Person Performing Calibration	Instrument Settings		Instrument Readings		Calibration Standard (Lot No.)	Remarks and Comments
			Pre-calibration	Post-calibration	Pre-calibration	Post-calibration		

APPENDIX D

MANHOLE AND EQUIPMENT SPECIFICATIONS

CNI MANUFACTURING

ECONOMY MANHOLES



SPECIFICATIONS:

- **Outer ring:** Rolled steel ring.
- **Skirt:** 14 gauge Galvanized sheet metal.
- **Cover:** 3 /8" reinforced floor plate, complies with h_2o rating
- **Gasket:** Low swell H.N.B.
- **Bolt down:** 3/8" hex bolt lock down
- ***12"**- 2 bolts
- ***16",18",24",30",and37"** - 4 bolts
- ***42"**- 6 bolts
- ***48"**- 8 bolts

3/8" FLOOR PLATE

ROUND ECONOMY MANHOLES

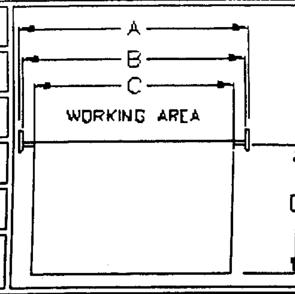
ROLLED STEEL RINGS WITH 12"SKIRT LENGTHS

ONE LIFT HANDLE	RAINTIGHT	PRICE	STANDARD	PRICE
24"	8034	157.00	8033	154.00
30"	8039	223.00	8038	217.00

TWO LIFT HANDLE	RAINTIGHT	PRICE	STANDARD	PRICE
37"	8044	320.72	8043	317.00
42"	8049	513.00	8048	509.00
48"	8054	680.00	8053	670.00

MANHOLE DIMENSIONS

SIZE	DIM "A"	DIM "B"	DIM "C"	DIM "D"	REINFD.
24"	24 1/2"	24"	22"	12"	YES
30"	30 1/2"	30"	28"	12"	YES
37"	37 1/2"	37"	34"	12"	YES
42"	42 1/2"	42"	39"	12"	YES
48"	48 1/2"	48"	45"	12"	YES



Home | Back | Prices | E-Mail | Order

How to Order the iSOC

- ISOCs sell for US$3500 each: Or lease for $300 per/month with 6-month minimum.
- All invoicing and purchase orders are handled by inVentures Technologies Incorporated, in Oakville, Ontario Canada. iTi will send an invoice regarding your purchase, which will also include shipping via UPS. (Please specify if you want regular or 3-day shipping).
- iTi will ship the order upon receipt of signed customer purchase order and 30% down payment with balance in 30 days.
- You will need to supply Performance Technologies, Inc. with billing information (company name, contact person, billing address, phone and fax numbers and Fed ID#) and the contact name, address, phone and fax numbers for shipping.
- You will mail or fax (we strongly recommend fax) your Purchase Order to:

inVentures Technologies, Inc.
2177 Oakmead Blvd.
Oakville, ON L6H 5N4
CANADA
Attn: John H. Archibald
Tel: (905) 339-1543
Fax (905) 339-1923

What you will need for Installation and Operation:

- You will need one flow meter for each iSOC. We recommend one of the following vendor parts (Check for prices):

  Cole Parmer 03217-00, plus fittings (about $125.00 each)
  www.coleparmer.com
  Tel: 800-323-4340; Fax 847-247-2929

  Dwyer RMA-151-SSV (specify 1/4" outside diameter fitting for polyethylene tubing) About $37.00 each.
  www.dwyer-inst.com
  Tel: 219-879-8000; Fax 219-872-9057

- 1/4" polyethylene tubing which can be purchased from several places:

  Home Depot: SKU #694889, online catalogue at www.homedepot.com , or local stores nationwide.

  Grainger Supplies, #4HM13, page 3016 of catalogue, or www.grainger.com , or local stores nationwide.

- Industrial Oxygen Tank. For each installation, you will need one (or more, depending on your setup design). Industrial gas supply companies generally rent these tanks: You will need a two-stage, low flow regulator.